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THE SCIENTIFIC MONTHLY

JUNE, 1921

THE BIOLOGY OF DEATH—IV. THE CAUSES OF DEATH[1]

By Professor RAYMOND PEARL

THE JOHNS HOPKINS UNIVERSITY

I. Classification of The Causes of Death

WE have seen in earlier papers that natural death of the metazoan body comes about fundamentally because of the differentiation of structure and function in that body. It is a complex aggregate of cells and tissues, all mutually dependent upon each other and in a delicate state of adjustment and balance. If one organ for any accidental reason, whether internal or external, fails to function normally it upsets this delicate balance, and if normal functioning of the part is not restored, death of the whole organism eventually results. Furthermore, we have been impressed by the fact that death does not strike in a haphazard or random manner, but instead in a most orderly way. There are certain periods of life—notably youth—where only an insignificant fraction of those exposed to risk ever die. At other ages, as, for example, extreme old age and early infancy, death strikes with appalling precision and frequency. Further we recall with Seneca that *nascimus uno modo multis morimur*. Truly there are many ways of dying. The fact is obvious enough. But what is the biological meaning of this multiplicity of pathways to the River Styx? There is but one pathway into the world. Why so many to go out? To the consideration of some phases of this problem I invite attention in this paper.

By international agreement among statisticians the causes of human mortality are, for statistical purposes, rather rigidly defined and separated into something over 180 distinct units. It should be clearly understood that this convention is distinctly and essentially statistical in its nature. In recording the statistics of death the registrar is confronted with the absolute necessity of putting every death record into

[1]Papers from the Department of Biometry and Vital Statistics, School of Hygiene and Public Health, Johns Hopkins University, No. 31.

some category or other in respect of its causation. However complex biologically may have been the train of events leading up to a particular demise, the statistician must record the terminal "cause of death" as some particular thing. The International Classification of the Causes of Death is a code which is the result of many years' experience and thought. Great as are its defects in certain particulars, it nevertheless has certain marked advantages, the most conspicuous of which is that by its use the vital statistics of different countries of the world are put upon a uniform basis.

The several separate causes of death are grouped in the International Classification into fourteen general classes. These are:

I. General diseases.
II. Diseases of the nervous system and of the organs of special sense.
III. Diseases of the circulatory system.
IV. Diseases of the respiratory system.
V. Diseases of the digestive system.
VI. Non-venereal diseases of the genito-urinary system and annexa.
VII. The puerperal state.
VIII. Diseases of the skin and of the cellular tissue.
IX. Diseases of the bones and organs of locomotion.
X. Malformation.
XI. Early infancy.
XII. Old age.
XIII. External causes.
XIV. Ill-defined diseases.

Perhaps the most outstanding feature which strikes one about the International List is that it is not primarily a biological classification. Its first group, for example, called "General Diseases," which caused in 1916 in the Registration Area of the United States approximately one-fourth of all the deaths, is a most curious biological and clinical mélange. It includes such diverse entities as measles and malaria, tetanus and tuberculosis, cancer and gonococcus infection, alcoholism and goiter, and many other unlike causes of death. For the purposes of the statistical registrar it perhaps has useful points to make this "General diseases" grouping, but it clearly corresponds to nothing natural in the biological world. Again in such parts of the scheme as do have some biological foundation the basis is different in different rubrics. Some have an organological basis, while others have a causational.

For purposes of biological analysis I developed some time ago an entirely different classification of the causes of death, on what I think is a reasonably consistent basis. The underlying idea of this new classification was to group all causes of death under the heads of the several organ systems of the body, the functional breakdown of which is the immediate or predominant cause of the cessation of life. All except a few of the statistically recognized causes of death in the International Classification can be assigned places in such a biologically

grouped list. It has a sound logical foundation in the fact that, biologically considered, death results because some organ system, or group of organ systems, fails to continue its functions.

The headings finally decided upon in the new classification were as follows:

I. Circulatory system, blood and blood-forming organs.
II. Respiratory system.
III. Primary and secondary sex organs.
IV. Kidneys and related excretory organs.
V. Skeletal and muscular systems.
VI. Alimentary tract and associate organs concerned in metabolism.
VII. Nervous system and sense organs.
VIII. Skin.
IX. Endocrinal system.
X. All other causes of death.

The underlying idea of this rearrangement of the causes of death is to put all those lethal entities together which bring about death because of the functional organic breakdown of the same general organ system. The cause of this functional breakdown may be anything whatever in the range of pathology. It may be due to bacterial infection; it may be due to trophic disturbances; it may be due to mechanical disturbances which prevent the continuation of normal function; or to any other cause whatsoever. In other words; the basis of the classification is *not* that of pathological causation, but it is rather that of organological breakdown. We are now looking at the question of death from the standpoint of the pure biologist, who concerns himself not with what causes a cessation of function, but rather with what part of the organism ceases to function, and therefore causes death.

In a series of papers already published I have given a detailed account of this classification, and the reasoning on which particular causes of death are placed in it where they are. Space is lacking here to go into the details, and I must consequently ask the reader either to take it on faith for the time being that the classification is at least a fairly reasonable one, or to take the trouble to go over it in detail in the original publication.[2]

2. General Results of Biologically Classified Death Rates

Here I should like to present first some general statistical results of this new classification. The data which we shall first discuss were in the form of death rates per hundred thousand living at all ages from various causes of death, arranged by organ systems primarily concerned in death from specified diseases. The statistics came from three

[2]Cf. particularly Pearl, R. "On the embryological basis of human mortality." (Proc. Natl. Acad. Sci. Vol. 5, pp 593-598, 1919) and "Certain evolutionary aspects of human mortality rates." (Amer. Natl. Vol. LIV. pp. 5-44, 1920). The following section as well as section 4 of this paper are largely based upon the second of the two papers.

widely separated localities and times, viz., (a) from the Registration Area of the United States; (b) from England and Wales; and (c) from the City of Sao Paulo, Brazil.

The summarized results are shown in graphic form in Fig. 1.

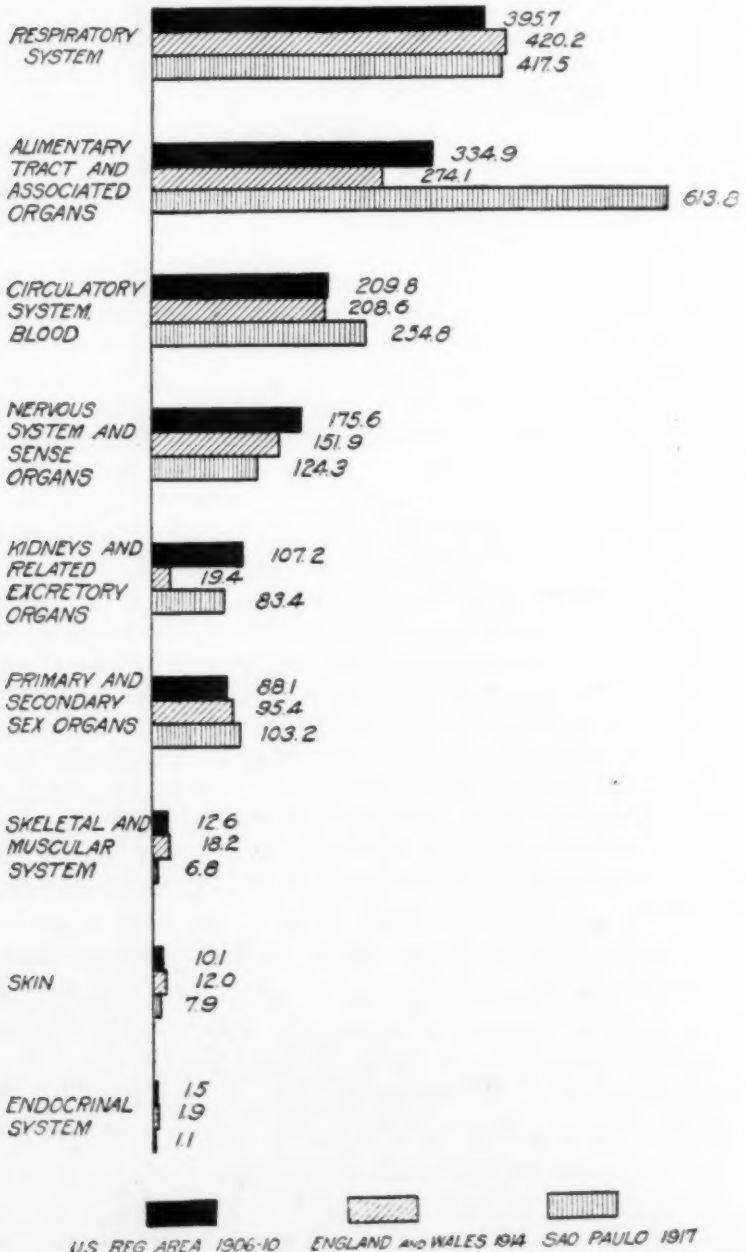


FIG. 1. SHOWING THE RELATIVE IMPORTANCE OF THE DIFFERENT ORGAN SYSTEMS IN HUMAN MORTALITY

In the United States, during the decade covered, more deaths resulted from the breakdown of the respiratory system than from the failure of any other organ system of the body. The same thing is true of England and Wales. In Sao Paulo the alimentary tract takes first position, with the respiratory system a rather close second. The tremendous death rate in Sao Paulo chargeable to the alimentary tract is chiefly due to the relatively enormous number of deaths of infants under two from diarrhea and enteritis. Nothing approaching such a rate for this catagory as Sao Paulo shows is known in this country or England.

In all three localities studied the respiratory and the alimentary tract together account for rather more than half of all the deaths biologically classifiable. These are the two organ systems which, while physically internal, come in contact directly at their surfaces with environmental entities (water, food, air) with all their bacterial contamination. The only other organ system directly exposed to the environment is the skin. The alimentary canal and the lungs are, of course, in effect invaginated *surfaces* of the body. The mucous membranes which line them are far less resistant to environmental stresses, both physical and chemical, than is the skin with its protecting layers of stratified and cornified epithelium.

The organs concerned with the blood and its circulation—the heart, arteries and veins, etc.—stand third in importance in the mortality list. Biologically the blood, through its immunological mechanism, constitutes the second line of defense which the body has against noxious invaders. The first line is the resistance of the outer cells of the skin and the lining epithelium of alimentary tract, lungs, and sexual and excretory organs. When invading organisms pass or break down these first two lines of defense the battle is then with the home guard, the cells of the organ system itself, which, like the industrial workers of a commonwealth keep the body going as a whole functioning mechanism. Naturally it would be expected that the casualties would be far heavier in the first two defense lines (respiratory and alimentary systems and the blood and circulation) than in the home guard. Death rates when biologically classified bear out this expectation.

It is at first thought somewhat surprising that the breakdown of the nervous system is responsible for more deaths than that of the excretory system. When one bears in mind however the relative complexity of the two pieces of machinery it is perceived that the relative position of the two in responsibility for mortality is what might reasonably be expected.

In the United States the kidneys and related excretory organs are responsible for more deaths than the sex organs. This relation is re-

versed in England and Wales and in Sao Paulo. This difference is mainly due in the case of England to two factors premature birth and cancer. In Sao Paulo it is due to premature birth and syphilis. The higher premature birth rate for these two localities as compared with the United States might conceivably be explained in either of two ways. It might mean better obstetrics here than in the other localities, or it might mean that the women of this country as a class are somewhat superior physiologically in the matter of reproduction, when they do reproduce. The first suggestion seems definitely more improbable than the second. The higher apparent syphilis rate of Sao Paulo probably means nothing more than better reporting, a less prudish disinclination to report syphilis as a cause of death in Sao Paulo than in the other two countries. It is by no means beyond the bounds of possibility that if all deaths really due to syphilis and gonorrhea were actually reported as such, the rate for the sex organs would be decidedly higher than for the excretory organs in all countries.

The last three organ systems, skeletal and muscular system, skin and endocrinal organs, are responsible for so few deaths relatively as not to be of serious moment.

There is one general consequence of these results upon which I should like to dwell a moment longer. In a broad sense the efforts of public health and hygiene have been directed against the affections comprised in the first two items in the chart, those of the respiratory system and the alimentary tract. The figures for the two five-year periods in the United States, 1901-05 and 1906-10, indicate roughly the rate of progress such measures are making, looking at the matter from a broad biological standpoint. In reference to the respiratory system there was a decline of fourteen per cent in the death rate between the two periods. This is substantial. It is practically all accounted for in phthisis, lobar pneumonia and bronchitis. For the alimentary tract the case was not so good—indeed far worse.

Between the two periods the death rate from this cause group fell only 1.8 per cent. All the gain made in typhoid fever was a great deal more than offset by diarrhea and enteritis (under two), congenital debility and cancer. Child welfare, both prenatal and postnatal, seems by long odds the most hopeful direction in which public health activities can expect at the present time substantially to reduce the general death rate. This is a matter fundamentally of education. Ignorant and stupid people must be taught, gently if possible, forcibly if necessary, how to take care of a baby, both before and after it is born. It seems at present unlikely, that mundane law will regard feeding cucumber to a two months' old baby, or dispensing milk reeking with deadly poison makers, as activities accessory to first-degree murder.

But we are moving in that direction under the enthusiastic and capable leadership of the Federal Children's Bureau. And there is this further comfort, that if that final Judgment Seat, before which so many believe we must all eventually appear, dispenses the even-handed justice which in decncy it must, many of our most prominent citizens who in the financial interests of themselves or their class block every move towards better sewage disposal, water and milk supply, and the like, or force pregnant women to slave over a washtub and sewing bench that they may live, will find themselves irrevocably indicted for the wanton and willful slaughter of innocent babies.

3. Specific Death Rates Biologically Classified

Up to this point in our discussions we have been dealing with crude death rates uncorrected for the age and sex distributions of the populations concerned. It is, of course, a well known fact that differences in age and sex constitution of populations may make considerable differences in crude death rates in cases where no real differences in the true force of mortality exist. What is essential for the further prosecution of the analysis of the causes of death is to get *specific* death rates for the several causes. By an age and sex specific death rate is meant the rate got by dividing the number of persons of a *particular specified age and sex* dying from a particular cause by the total number of persons living in the same population *of the same age and sex*. In other words we need to get as the divisor of our rate fraction the number of persons who can be regarded as truly exposed to risk. This exposed-to-risk portion of the population is never correctly stated in a crude death rate. For example, a person now 75 years old can not be regarded as exposed to risk of death at age 45. He was once exposed to that risk but passed it safely. Yet in a crude death rate he is counted with those of age 45.

With the aid of Dr. William H. Davis, director of vital statistics in the Census Bureau, who very kindly provided me with the necessary unpublished data, it has been possible to calculate the specific death rates for each of the 189 causes of death of the International List, for each sex separately, and for each age in 5 year groups, for the United States Registration Area exclusive of North Carolina, in 1910. These results have been put together in the biological scheme of classification and may be presented briefly in the form of diagrams.

Let us first consider deaths from all causes taken together, in order to refresh our memories as to the general form of a death rate curve. It will be noted at once that the rates are plotted along the vertical axis on what strikes one at first as a peculiar scale. The scale is logarithmic. The horizontal lines are spaced in proportion to the logarithms of the numbers at their left, instead of in proportion to the numbers themselves. The advantages of this method of plotting in the present case

are two-fold. First, it is possible to get a much wider range of values on the diagram; and second the logarithmic scale permits direct and accurate estimation of the rate of change of a variable. A straight line forming an angle with the horizontal on a logarithmic scale means that the variable is increasing or decreasing, as the case may be, *at a constant rate of change.*

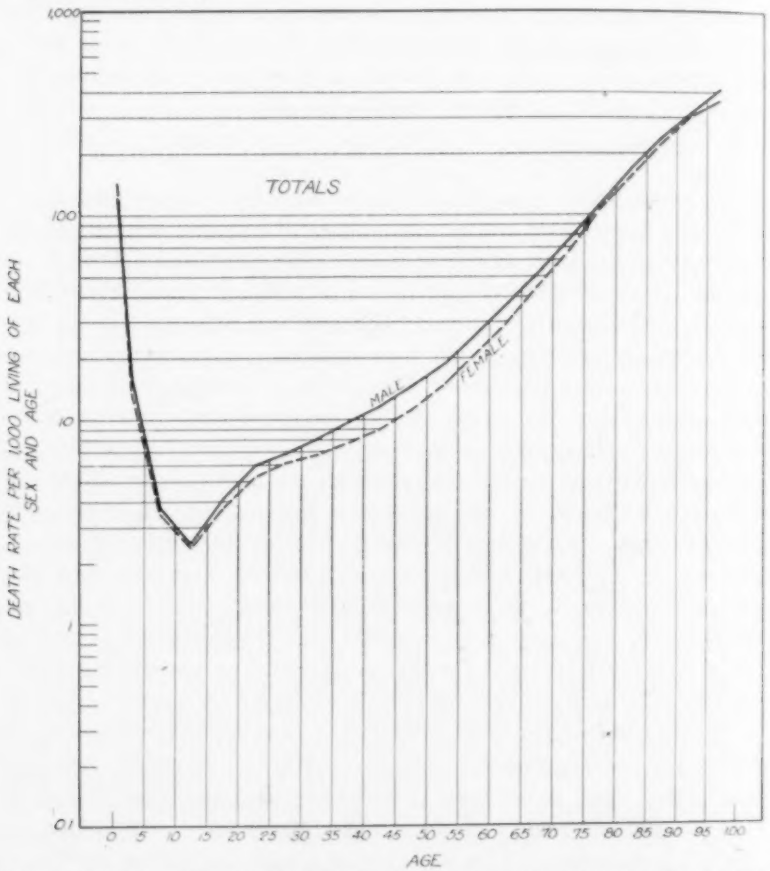


FIG. 2. DIAGRAM SHOWING THE SPECIFIC DEATH RATE AT EACH AGE FOR DEATHS FROM ALL CAUSES TAKEN TOGETHER

Fig. 2 gives the specific death rates for the combined total of all causes. The curve in general has the form of a V with one limb much extended and pulled over to the right. Examining it more in detail, we note that in the first year of life the specific death rate, or, as we may roughly call it, the force of mortality, bears heavier on female infants than on the males. Out of a thousand exposed to risk, 124 male babies die in that year, and 143 female. This is the only year of life in which the total force of mortality is heavier among females than males. From

that time on to the end of the span of life the female curve lies, by greater or less amounts, below the male curve. After the heavy mortality of early infancy, the curve drops in almost a straight line to the age period 10-15, where it reaches its lowest point, and only approximately 2½ persons out of a thousand exposed to risk die. The specific mortality curve then begins to rise and continues to do so at an approximately constant and rapid rate for ten years—that is to the age period 20-25. From then on to the age period 50-55 it rises at a slower but constant rate. This is the period of middle life, and here the female curve drops farther below the male curve than at any other place in the span of life. After the age period 50-55 with the on-coming of old age, both male and female curves begin again to rise more rapidly. They continue this rise at a practically constant rate of increase to the end of life, which is here taken as falling in the age period 95-100. In

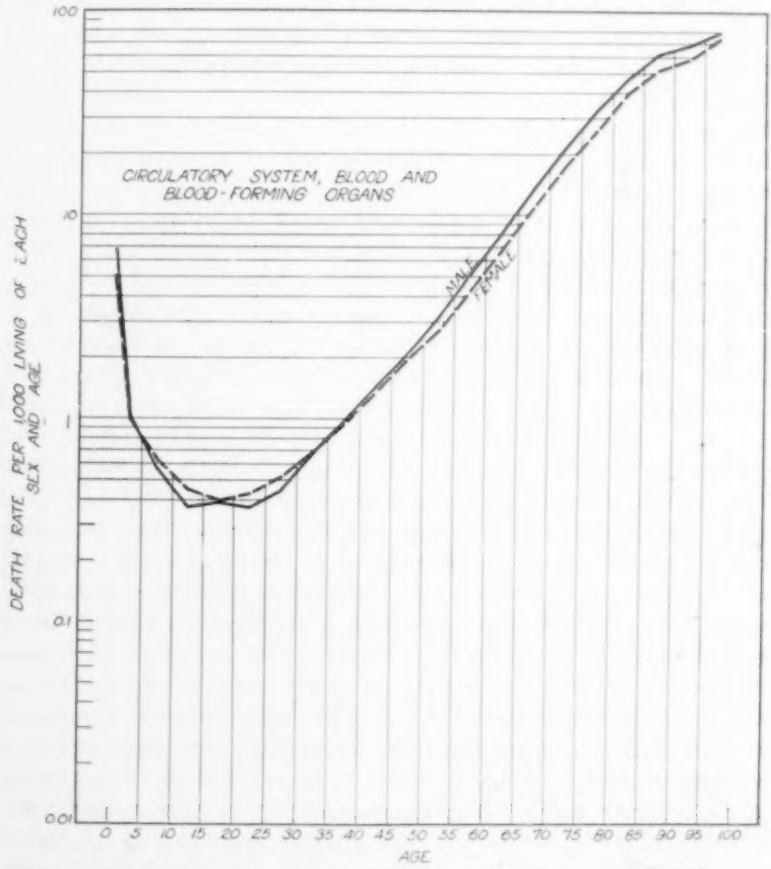

CIRCULATORY SYSTEM, BLOOD AND BLOOD-FORMING ORGANS
MALE
FEMALE
DEATH RATE PER 1000 LIVING OF EACH SEX AND AGE
100
10
1
0.1
0.01
0 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90 95 100
AGE

FIG. 3. DIAGRAM SHOWING THE SPECIFIC DEATH RATE AT EACH AGE FROM BREAKDOWN OF THE CIRCULATORY SYSTEM, BLOOD AND BLOOD FORMING ORGANS

this last class the rate has become very high. Out of 1,000 persons living at the ages of 95 and 100, and therefore exposed to risk of death within that period, 494 males and 473 females die, taking an average for the whole five-year period. Of course, before the completion of the period, practically all of the thousand will have passed away.

The important things to note about this curve are these: First, the highest specific forces of mortality occur at the extreme ends of life, and are higher at the final end than at the beginning. In the second place, there is a sharp and steady drop in almost a straight line from the high specific force of mortality in infancy to the low point at about the time of puberty. From then on to the end of the span of life the force of mortality becomes greater every year at a nearly constant rate of increase with only such slight deviations from this constancy of rate as have already been pointed out.

Turning next to the mortality of our first biological group—namely, deaths caused by breakdown of the circulatory system, blood and blood forming organs—we note a marked difference in the form of the curve from what we have seen for the case of all causes of death. In the first place, the specific force of mortality of this group of causes is relatively low in infancy and childhood. Out of a thousand infants of each sex exposed to risk, only 7 males and 5 females die from breakdown of this group of organs during the first year of life. The trough of the curve associated with the mortality of childhood and youth is very much less pointed than in the case of "all causes." It is a smoothly rounded, rather than a sharply pointed depression. It is also noteworthy that between approximately the ages of 5 and 35 the specific force of mortality from diseases of the circulatory system and related organs is higher for females than it is for males. This condition of affairs is probably connected with the graver physiological changes and readjustments called forth by puberty in the female than accompany the same vital crisis in the male. From early adult life, say age 25-30 on, the specific death rate from diseases of the circulatory system and related organs increases at an almost absolutely constant rate until age 85 is reached. After that the rate of increase slows down somewhat. Of those reaching the age 95-100, between 70 and 80 out of each thousand living die from breakdown of this group of organs.

The specific mortality curve for deaths from breakdown of the respiratory system, as shown in Fig. 4, presents a number of points of peculiar interest. In the first place we note that this organ system is much more liable to breakdown than is the circulatory system during all the earlier years of life up to about age 60-65. The decline in the curve from the high point of infancy to the low point of the period about puberty is more sharp and sudden than that of the circulatory system curve. Again, however, just as in the former case, we note that

the specific force of mortality from breakdown of this organ system impinges more heavily upon females than upon males in the years from 5-20. This difference is probably connected, as before, with the greater physiological disturbance of puberty in the female than in the male. The lowest point of the respiratory curve falls in the age group 10-15. Between the ages 25-70 there is a very striking difference in the two sexes in respect of specific mortality from breakdown of the respiratory system. The male curve rises in nearly a straight line, while the female curve lies far below it, and actually shows a point of inflection at about age 45 becoming for a short period convex to the base. The explanation for the great separation of the two curves in this period is probably fundamentally occupational. From the nature of their activity males during this period of life are probably subject to a greater risk of breakdown of the respiratory system than are the more protected female lives. From age 70 on, both curves ascend with

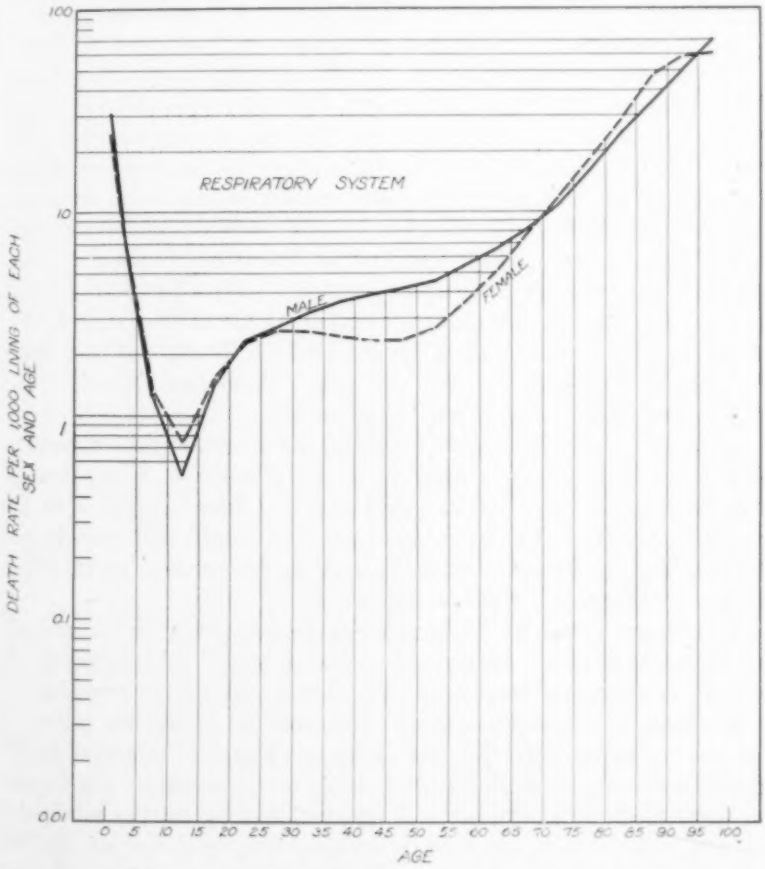


FIG. 4. DIAGRAM SHOWING THE SPECIFIC DEATH RATE AT EACH AGE FROM BREAKDOWN OF THE RESPIRATORY SYSTEM

increased rapidity, the female curve rising above the male, presumably in compensation for the marked dip which it exhibits in middle life. It is, of course, well known that respiratory mortality bears heavily upon the aged.

The next group which we shall consider has to do with deaths from breakdown of the primary and secondary sex organs. This cause group furnishes an extremely interesting pair of curves shown in Fig. 5. Before discussing in detail their form a word of explanation as to their makeup should be given. In this rubric are included "Premature birth" and "Injuries at birth." The question at once arises, why should these two items, "Premature birth" and "Injuries at birth" be included with the primary and secondary sex organs, since it is obvious enough that the infants whose deaths are recorded under these heads in the vast majority of cases, if not all, have nothing whatever the matter with either their primary or secondary organs. The answer is, in general terms, that on any proper biological basis, deaths coming under of these two categories are not properly chargeable organically against the infant at all, but should be charged, on such a basis, against the mother. To go further into detail, it is apparent that when a premature birth occurs it is because the reproductive system of the mother, for some reason or other, did not rise to the demands of the situation of carrying the foetus to term. Premature birth, in short, results from a failure or breakdown in some particular of the *maternal reproductive system*. This failure may be caused in various ways, which do not here concern us. The essential feature from our present viewpoint is that the reproductive system of the mother does breakdown, and by so doing causes the death of the infant, and that death is recorded statistically under this title "Premature birth." The death organically is chargeable to the mother.

A considerable number of cases of premature birth are unquestionably due to placental defects and the placenta is a structure of foetal origin, so such deaths could not be properly charged to the mother. On the other hand, however, they would still stay in the same table because the placenta may fairly be regarded as an organ intimately concerned in reproduction.

The same reasoning which applies to premature births, *mutatis mutandis*, applies to the item "Injuries at birth." An infant death recorded under this head means that some part of the reproductive mechanism of the mother, either structural or functional, failed of normal performance in the time of stress. Usually "injury at birth" means a contracted or malformed pelvis of the mother. But in any case the death is purely external and accidental from the standpoint of the infant. It is organically chargeable to a defect of the sex organs of the mother. The female pelvis, in respect of its conformation, is a secondary sex character.

Turning now to the consideration of Fig. 5, which gives the curves of specific mortality from breakdown of the reproductive organs we note at once the high specific death rate of infants under one recorded by the female line. This rate is over 40 per thousand exposed to risk. It includes of course both male and female infants dying from congenital debility, premature birth and injuries at birth, because according to the reasoning just explained these deaths are organically chargeable to breakdown or failure to function properly of the reproductive organs of the mother. These deaths, therefore, go into the female group. By the fifth year of life the specific rates of mortality chargeable to reproductive organs have dropped in both sexes practically to zero, amounting to less than 0.01 per thousand exposed to risk. At about the time of puberty the female curve begins to rise and goes up very steeply. By age 30 it has reached a value of 1 per thousand ex-

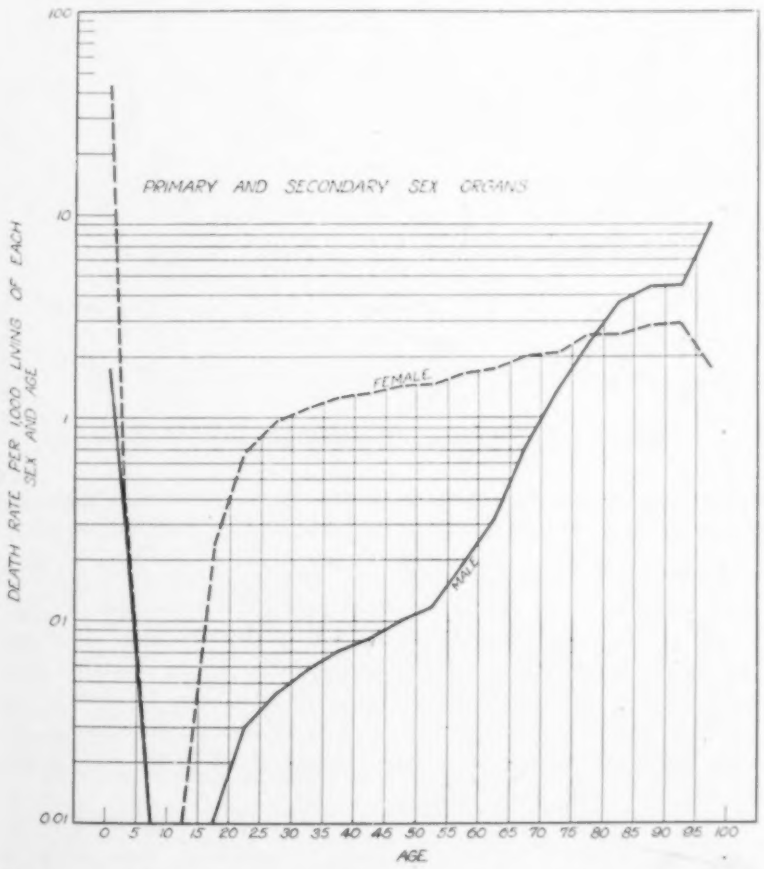

PRIMARY AND SECONDARY SEX ORGANS
DEATH RATE PER 1000 LIVING OF EACH SEX AND AGE
100
10
1
01
001
FEMALE
MALE
0 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90 95 100
AGE

FIG. 5. DIAGRAM SHOWING SPECIFIC DEATH RATES AT EACH AGE FROM BREAKDOWN OF THE PRIMARY AND SECONDARY SEX ORGANS

posed to risk. From that point the force of this specific mortality rises slowly, but at a practically constant rate, to extreme old age. The

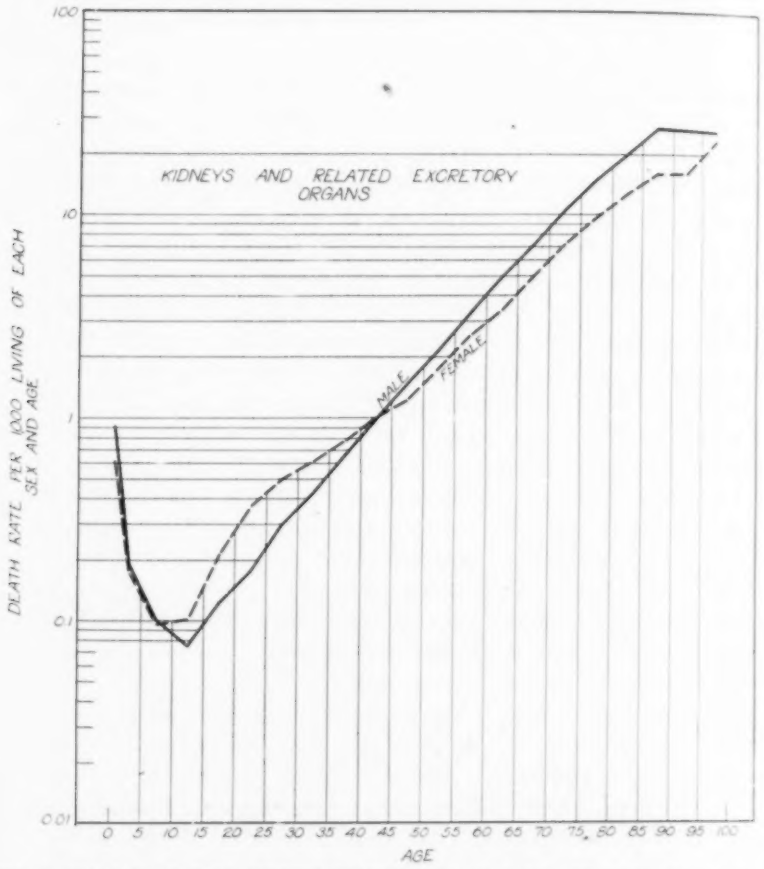

KIDNEYS AND RELATED EXCRETORY ORGANS
DEATH RATE PER 1000 LIVING OF EACH SEX AND AGE
100
10
1
0.1
0.01
MALE
FEMALE
0 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90 95 100
AGE

FIG. 6. DIAGRAM SHOWING SPECIFIC DEATH RATES AT EACH AGE FROM BREAKDOWN OF THE KIDNEYS AND RELATED EXCRETORY ORGANS

male curve is in striking contrast to the female. From about age 20 it rises steadily, at an almost constant rate of increase, but a much slower one than the female, until the end of the life span. It crosses the female curve—indicating a higher specific rate of mortality from breakdown of the reproductive organs in men than in women—for the first time at about age 78. This is of course, the time of life when disturbed functioning of the prostate gland in the male begins to take a relatively heavy toll.

Fig. 6 shows specific rates of mortality from breakdown of the kidneys and related excretory organs. Death from these causes is relatively infrequent in infancy and early childhood. The low point

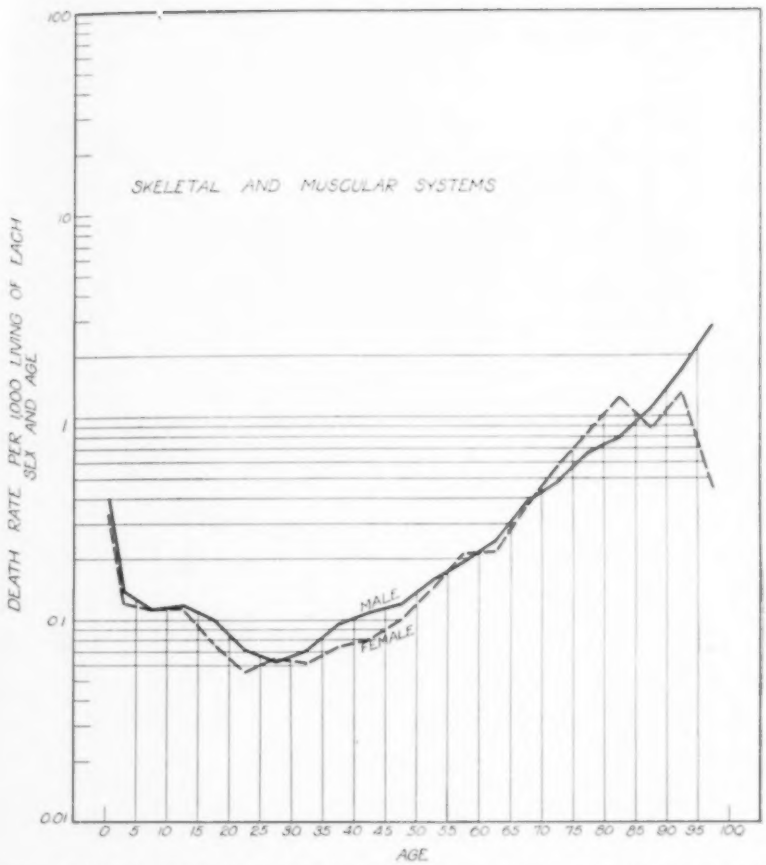


FIG. 7. DIAGRAM SHOWING SPECIFIC DEATH RATES AT EACH AGE FROM BREAKDOWN OF THE SKELETAL AND MUSCULAR SYSTEMS

is reached, as in so many of the other cases, at about the time of puberty. From then on practically to the end of the span of life the specific force of mortality from excretory failure increases at an almost constant rate. During the reproductive period from about 15 to 45 years of age specific rates of mortality from these causes are higher in the female than in the male. After that point the male curve is higher. The relatively heavy specific mortality of the female in early life is undoubtedly due to the heavy strain put upon her excretory organs by child-bearing.

The specific force of mortality from breakdown of the skeletal and muscular systems shown in Fig. 7 presents an interesting pair of curves. Throughout the span of life there is practically no difference between the female and male in the incidence of this mortality, the curves winding in and out about each other. The striking characteristics of the

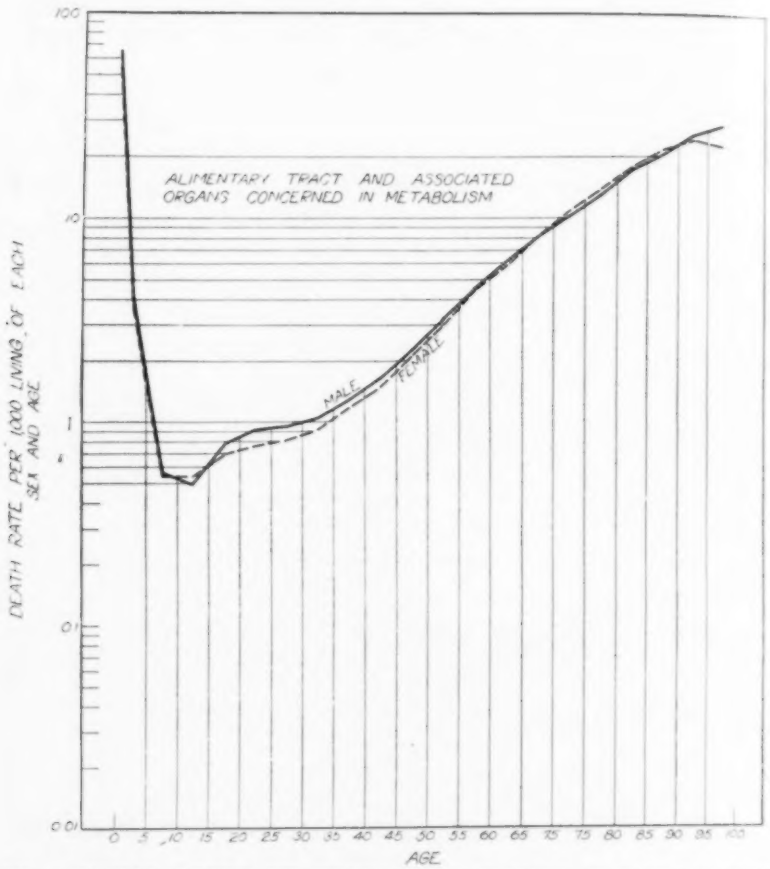

100
10
1
0.1
0.01
DEATH RATE PER 1000 LIVING OF EACH SEX AND AGE
ALIMENTARY TRACT AND ASSOCIATED ORGANS CONCERNED IN METABOLISM
MALE
FEMALE
0 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90 95 100
AGE

FIG. 8. DIAGRAM SHOWING THE SPECIFIC RATES OF DEATH AT EACH AGE FROM BREAKDOWN OF THE ALIMENTARY TRACT AND ASSOCIATED ORGANS OF METABOLISM

curve are: first, that the specific forces of mortality are absolutely low for these organ systems; and second, that the minimum point is reached not as in most of the other cases around the time of puberty, but at a much later period—namely in the late twenties. The whole curve shows a very gradual change in the rates.

The next diagram, Fig. 8, shows one of the most significant organ groups in the force of its specific mortality. Breakdown and failure to function properly of the primary organs of metabolism—the organs which transform the fuel of the human machine into vital energy—occur with relatively heavy frequency at all periods of life. These curves are among the few which show an absolutely higher specific force of mortality in infancy than in extreme old age. There is practically no significant difference between the male and female curve at any portion of life. During early adult life the female curve lies be-

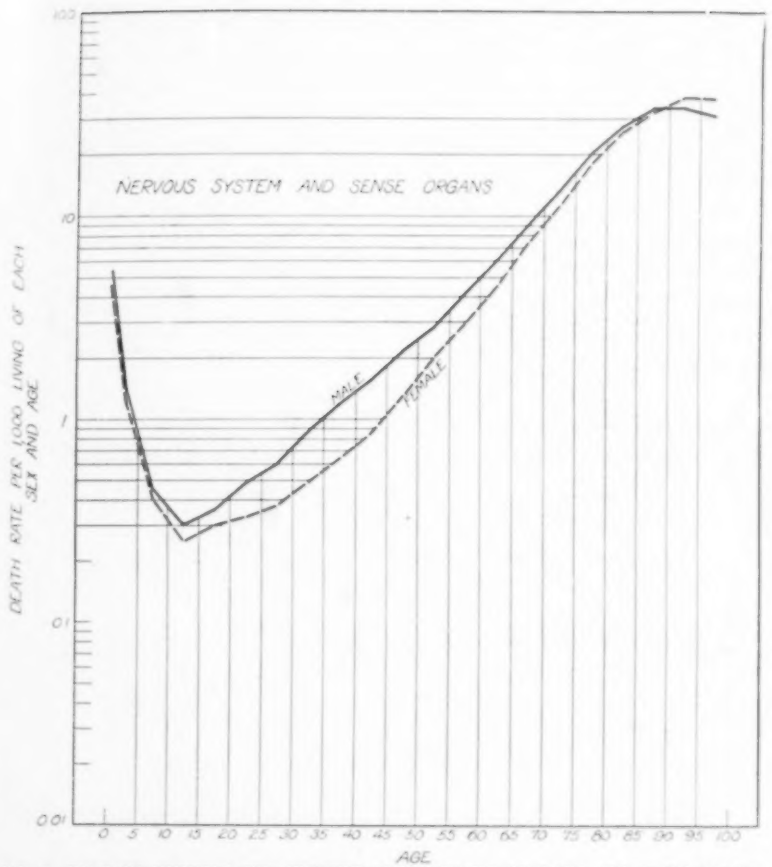

NERVOUS SYSTEM AND SENSE ORGANS
MALE
FEMALE
DEATH RATE PER 1,000 LIVING OF EACH SEX AND AGE
100
10
1
0.1
0.01
0 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90 95 100
AGE

FIG. 9. DIAGRAM SHOWING THE SPECIFIC DEATH RATES AT EACH AGE FROM BREAKDOWN OF THE NERVOUS SYSTEM AND SENSE ORGANS

low the male, but by only a small amount. Out of every thousand infants under one, about sixty die in the first year of life from breakdown of the alimentary tract and its associated organs. After the low point, which falls in the relatively early period of 7 to 12 years of age, there is a rapid rise for about ten years in the specific rates of mortality, followed by a slowing off in the rate of increase for the next ten or fifteen years, after which point the curve ascends at a practically uniform rate until the end of the span of life.

Fig. 9 shows the trend of the specific mortality from breakdown of the nervous system and sense organs. This organ group on the whole functions very well, giving a relatively low rate of mortality until towards the end of middle life. Then the specific rates get fairly large. The low point in this curve is, as in most of the others, at about the time of puberty. From then on to the end of the life span

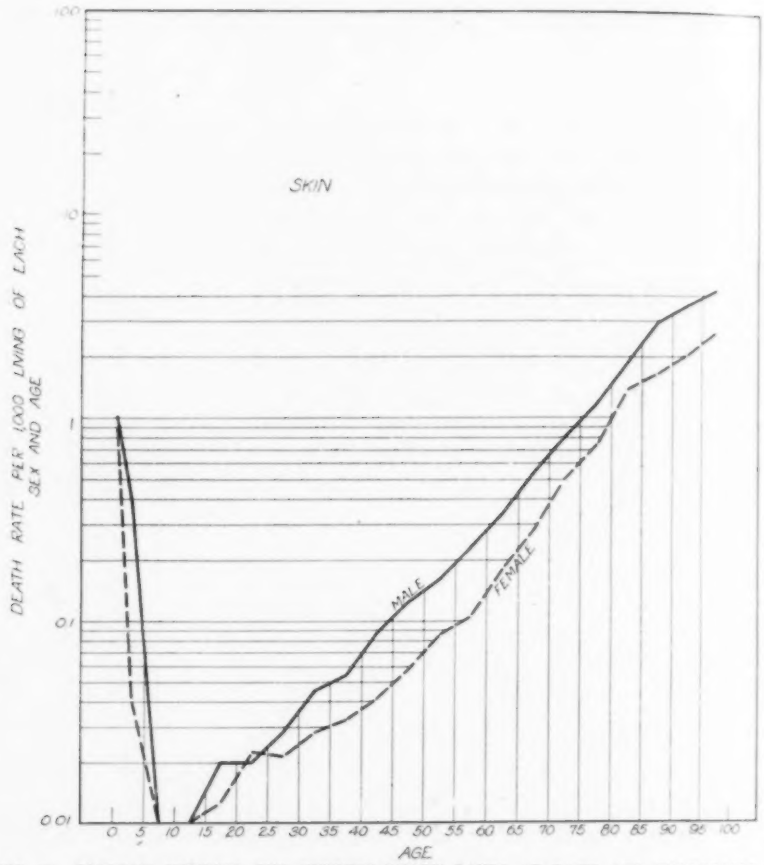


FIG. 10. DIAGRAM SHOWING THE SPECIFIC DEATH RATES AT EACH AGE CHARGEABLE AGAINST THE SKIN

the specific rates increase at a practically uniform rate. The female curve everywhere lies below the male curve except at the extreme upper end of the life span. Before that time, and particularly between the ages of 20 and 50, the business of living evidently either imposes no such heavy demand on the nervous system of the female as it does on that of the male, or else the nervous system of the female is organically sounder than that of the male. The former suggestion seems the more probable.

That breakdown and failure to function properly of the skin as an organ system is a relatively insignificant factor in human mortality is demonstrated by Fig. 10. From a specific death rate of about 1 per 1,000 in the first year of life it drops abruptly practically to zero in early childhood. At about the time of puberty it begins to rise again and ascends at a steady rate during all the remainder of life. The final high point reached is absolutely low, however, amounting to a

specific death rate among those exposed to risk of only a little more than 4 per 1,000 at the extreme end of life. The female curve lies well below the male curve practically throughout its course.

Deaths from failure to function properly of the organs of the endocrinal system, including the thyroid gland, suprarenal glands, etc., do not become significant until middle life in the case of the male, as shown in Fig. 11, although in the female the curve begins to rise from puberty on. The specific rates at all ages, of course, are extremely small, practically never rising to more than 1/10 of one person per 1,000 exposed to risk. The well-known fact that these glandular organs, whose secretions are so important for the normal conditions of life, are much more unstable and liable to breakdown in the female than in the male is strikingly shown by this diagram.

Finally, we have the diagram for our *omnium gatherum* group, the "All other causes of death," in Fig. 12. Here we see that because of

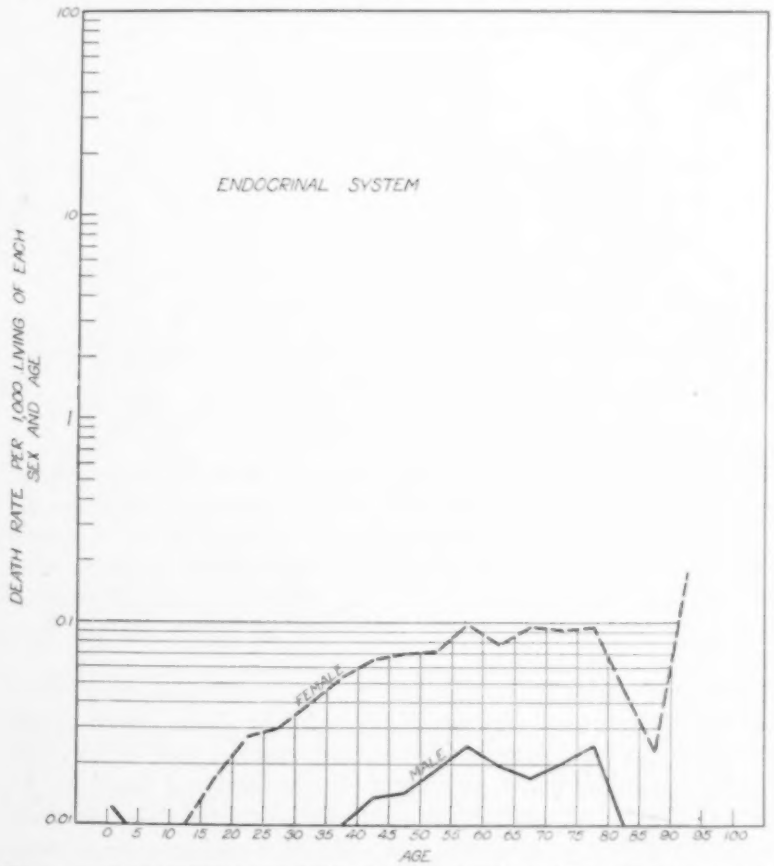


FIG. 11. DIAGRAM SHOWING THE SPECIFIC DEATH RATES AT EACH AGE FROM BREAKDOWN OF THE ENDOCRINAL SYSTEM

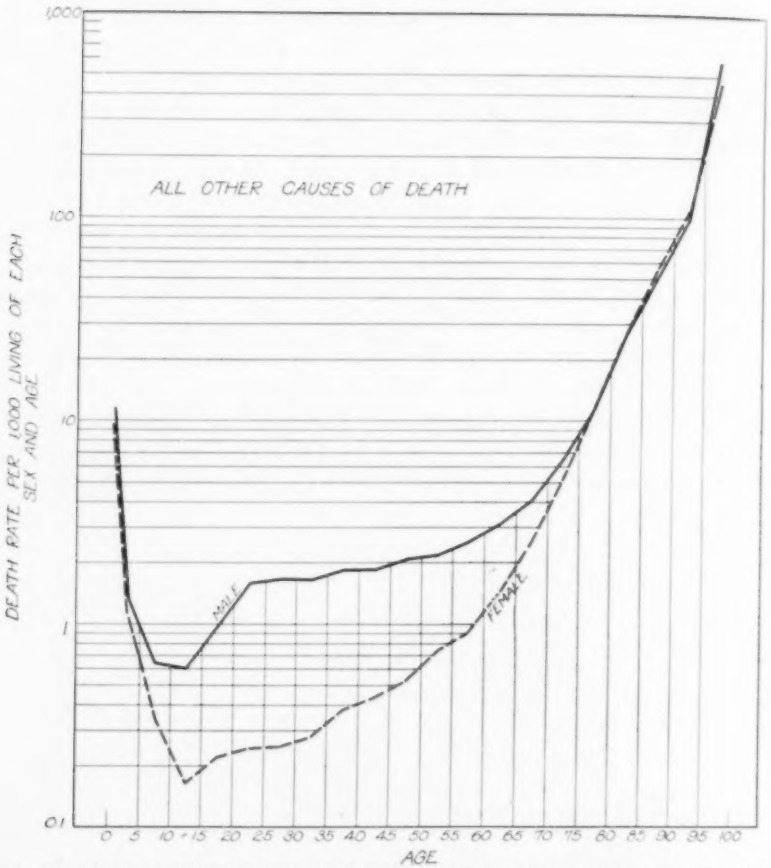


FIG. 12. DIAGRAM SHOWING THE SPECIFIC DEATHS FROM ALL OTHER CAUSES OF DEATH NOT COVERED IN THE PRECEDING CATEGORIES.

accidental and violent deaths the male specific mortality curve lies far above the female, from youth until old age has set in about age 75. From that point on to the end of the span of life both curves ascend rapidly together, as a result of the deaths recorded as resulting from senility. Eventually it is to be expected that no deaths will be registered as resulting from senility. We shall have them all put more nearly where they belong.

These diagrams of specific forces of mortality give altogether a remarkably clear and definite picture of how death occurs among men. We see that failure of certain organ systems, such as the lungs, the heart, the kidneys, to maintain their structural and functional integrity, has an overwhelmingly great effect in determining the total rate of mortality as compared with some of the other organ systems. One can not but be impressed too with the essential orderliness of the

phenomena we have examined. The probability of any particular organ system breaking down and causing death is mathematically definite at each age, and changes in a strikingly orderly manner as age changes, as is shown in Table 1. Thus we find that in the first year of life it is the alimentary tract and its associated organs which most frequently break down and cause death. From age 1 to age 60 the specific force of mortality from breakdown of the respiratory system is higher (with a few insignificant exceptions in the females) usually by a considerable amount, than that associated with any other organ system of the body. From 60 to 90 years of age the circulatory system takes the front rank, with a higher specific mortality rate than any other organ system.

TABLE 1.

The Most Fatal Organ Systems at Different Ages

MALES			FEMALES	
Per cent of all biologically classifiable deaths due to breakdown of specified organ system.	Most fatal organ system	Age Group	Most fatal organ system	Per cent of all biologically classifiable deaths due to breakdown of specified organ system.
68.8	Alimentary tract	0 — 1	Alimentary tract	40.6
50.1	Respiratory	1 — 4	Respiratory	51.3
41.2	"	5 — 9	"	42.5
27.1	"	10—14	"	33.3
43.6	"	15—19	"	43.8
52.6	"	20—24	"	46.0
49.7	"	25—29	"	44.2
45.6	"	30—34	"	39.5
39.9	"	35—39	"	33.2
33.3	"	40—44	"	27.5
28.0	"	45—49	"	22.1
23.6	"	50—54	Alimentary tract	21.6
25.0	Circulatory	55—59	"	22.6
28.4	"	60—64	Circulatory	24.4
30.9	"	65—69	"	25.6
32.5	"	70—74	"	28.0
32.9	"	75—79	"	28.4
33.3	"	80—84	"	30.4
		85—89	"	30.8

If our lungs were as organically good relatively as our hearts, having regard in each case for the work the organ is called upon to do and the conditions under which it must do it, we should live a considerable number of years longer on the average than we do now. One can not but feel that the working out of a rational and scientifically grounded system of personal hygiene of the respiratory organs, on the broadest basis, to include all such matters as ventilation of buildings, etc., and the putting of such a personal hygiene into general use

through education, would pay about as large dividends as could be hoped for from any investment in public health securities. I am aware that much has already been done in this direction, but in order to reap any such dividends as I am thinking of, a vast amount must be added to our present knowledge of the physiology, pathology, epidemiology, and every other aspect of the functions and structures of respiration.

4. The Embryological Basis of Mortality

Up to this point in our discussion we have confined our attention to the organological incidence of death. It is possible to push the matter of human mortality still farther back. In the embryological development of the vertebrate body, there are laid down at an early stage, in fact immediately following the process of gastrulation, three morphologically definite primitive tissue elements, called respectively the ectoderm, the mesoderm, and the endoderm. These are termed the

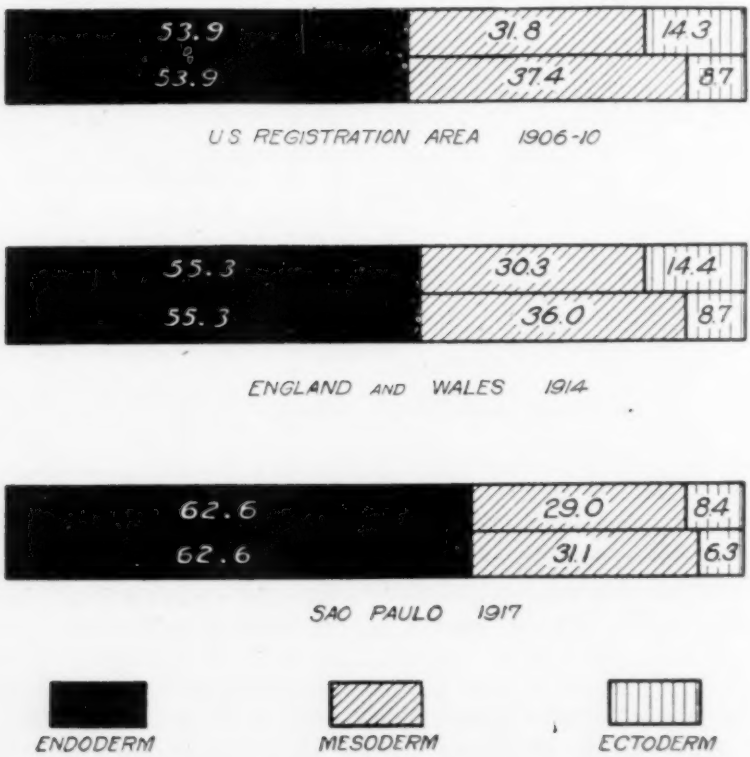


FIG. 13. DIAGRAM SHOWING THE PERCENTAGES OF BIOLOGICALLY CLASSIFIABLE HUMAN MORTALITY RESULTING FROM BREAKDOWN OF ORGANS DEVELOPING FROM THE DIFFERENT GERM LAYERS. Upper bar of pair gives upper limit of mortality chargeable to ectoderm; lower bar gives lower limit of mortality chargeable to ectoderm

germ-layers, and embryological science has, for a great many forms, succeeded in a broad way in tracing back to the primitive germ layer from which it originally started its development, substantially every one of the adult organs and organ systems of the body. It makes no difference to the validity or significance of the discussion which we are about to enter upon, in what degree of esteem or contempt in biological philosophy the germ layer theory or doctrine, which occupied so large a place in morphological speculation 50 years ago, may be held. We are here concerned only with the well established broad fact, that in general all adult organ systems may be traced back over the path of their embryological development to the germ layer, or combination of germ layers, from which they originally started.

Having arranged so far as possible all causes of death on an organological basis, it occurred to one to go one step further back and combine them under the headings of the primary germ layers from which the several organs developed embryologically. To do this was a task of considerable difficulty. It raised intricate, and in some cases still unsettled, questions of embryology. Furthermore, the original statistical rubrics under which the data are compiled by registrars of vital statistics were never planned with such an object as this in mind. Still the thing seemed worth trying because of the biological interest which would attach to the result, even though it were somewhat crude and in respect of minor and insignificant details open to criticism. It is not possible here to go into details as to how the causes of death were combined in making up the final tables. For these details one must refer to the original papers.

Fig. 13 gives the result for the crude mortality of the U. S. Registration Area, England and Wales, and Sao Paulo, Brazil. The figures show that in man, the highest product of organic evolution, about 57 per cent of all the biologically classifiable deaths result from a breakdown and failure further to function of organs arising from the endoderm in their embryological development, while but from 8 per cent to 13 per cent can be regarded as a result of breakdown of organ systems arising from the ectoderm. The remaining 30 to 35 per cent of the mortality results from failure of mesodermic organs. The two values stated for ectoderm and mesoderm, shown by the two bars in the diagram, differ by virtue of the fact that two important causes of death, cerebral hemorrhage and apoplexy, and softening of the brain, are put in the one case with the ectoderm and in the other case with the mesoderm. The pathological arguments for the one disposition as against the other of these two diseases are interesting, but lack of space prevents their exposition here. I have chosen rather to present the facts in both ways.

Taking a general view of comparative anatomy and embryology it

is evident that in the evolutionary history through which man and the higher vertebrates have passed it is the ectoderm which has been most widely differentiated from its primitive condition, to the validity of which statement the central nervous system furnishes the most potent evidence. The endoderm has been least differentiated in the process of evolution, while the mesoderm occupies an intermediate position in this respect.

Degree of differentiation of organs in evolution implies degree of adaptation to environment. From the present point of view we see that that germ layer, the endoderm, which has evolved or become differentiated least in the process of evolution is least able to meet successfully the vicissitudes of the environment. The ectoderm has changed most in the course of evolution. Of this the central nervous system of man is the best proof. There have also been formed in the process of differentiation, protective mechanisms, the skull and vertebral column, which very well keep the delicate and highly organized central nervous system away from direct contact with the environment. The skin also exhibits many differentiations of a highly adaptive nature to resist environmental difficulties. It is then not surprising that the organ systems developed from the ectoderm break down and lead to death less frequently than any other. The figures make it clear that man's greatest enemy is his own endoderm. Evolutionally speaking, it is a very old-fashioned and out-of-date ancestral relic, which causes him an infinity of trouble. Practically all public health activities are directed towards overcoming the difficulties which arise because man carries about this antediluvian sort of endoderm. We endeavor to modify the environment, and soften its asperities down to the point where our own inefficient endodermal mechanism can cope with them, by such methods as preventing bacterial contamination of water, food and the like, warming the air we breathe, etc. But our ectoderm requires no such extensive amelioration of the environment. There are at most only a very few if any germs which can gain entrance to the body through the normal, healthy, unbroken skin. We do, to be sure, wear clothes. But it is at least a debatable question whether upon many parts of the earth's surface we should not be better off without them from the point of view of health.

These data indicate further in another manner how important are the fundamental embryological factors in determining the mortality of man. Of the three localities compared, England and the United States may be fairly regarded as much more advanced in matters of public health and sanitation than Sao Paulo. This fact is reflected with perfect precision and justice in the relative proportion of the death rates from endoderm and ectoderm. In the United States and England about 55 per cent. of the classifiable deaths are chargeable

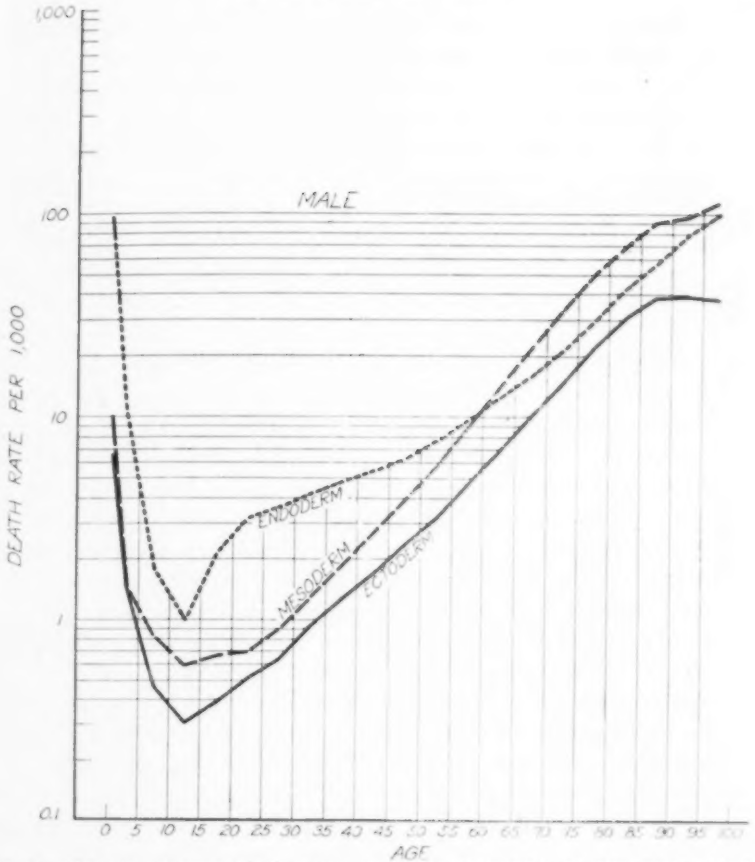


FIG. 14. SHOWING SPECIFIC DEATH RATES IN MALES ACCORDING TO THE GERM LAYER FROM WHICH THE ORGANS DEVELOPED WHERE BREAKDOWN LEADS TO DEATH

to endoderm and about 9 to 14.5 per cent to ectoderm. In Sao Paulo 62.6 per cent. fall with the endoderm, and but 6.3 to 8.4 per cent. with the ectoderm. Since, as we have already shown, public health measures can and do affect practically only the death rate chargeable to endoderm this result which is actually obtained is precisely that which would be expected.

A question which naturally occurs is as to what the age distribution of breakdown of ectodermic, mesodermic, or endodermic organs may be. Are the endodermic organs for example relatively more liable to breakdown in early life, and less so later, as general observation would lead one to conclude?

To answer this and similar questions which come to mind we need to distribute our specific rates upon an embryological basis.

In Fig. 14 the result of doing this is shown for males. We note that prior to age 60 the curve for the breakdown of organs of endo-

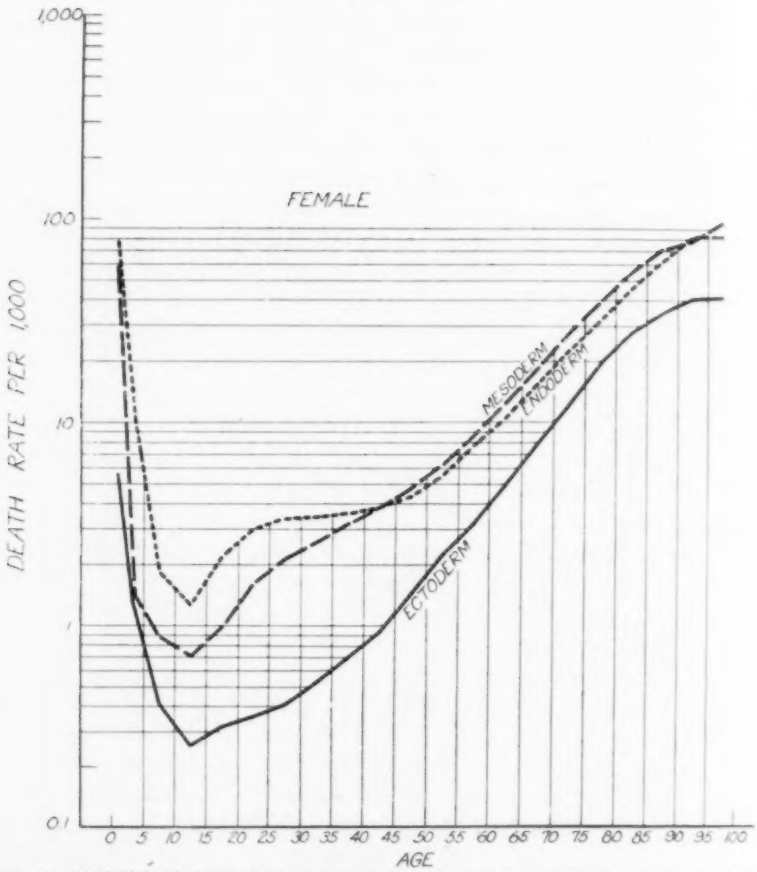


FIG. 15. SHOWING SPECIFIC DEATH RATES FOR FEMALES, CLASSIFIED IN THE SAME MANNER AS IN FIG. 14

dermic origin lies at the top of the diagram; next below it comes the curve for the breakdown of organs of mesodermic origin; and finally at the bottom the curve for the breakdown of organs of ectodermic origin. All three of the curves have in general the form of a specific death rate curve. The rates for all three germ layers are relatively high in infancy and drop at a practically constant rate to a low point in early youth. In infancy the heaviest mortality in males is due to the breakdown of organs of endodermic origin. This part of the death rate accounts for something like 10 times as many deaths as either mesoderm or ectoderm at this period of life. From about age 12 on in the case of organs of ectodermic origin, and from about age 22 on in cases of mesodermic origin, the death rate curves rise at a practically constant rate to extreme old age. The ectodermic and mesodermic curves during this portion of the life span are nearly parallel, diverging only slightly from each other with advancing age.

The curve for the death rate resulting from breakdown of organs of endodermic origin has an entirely different course. It rises sharply for ten years after the low point in early youth, and then makes a rather sharp bend at about age 22, and passes off to the end of the life span, at a reduced rate of change. In consequence of this it crosses the mesodermic line at age 60. From that point on to the end of life deaths from breakdown of organs of mesodermic origin stand first in importance.

Fig. 15 shows the same set of facts for the female, and at once a number of striking differences between the conditions in the two sexes appear. In the first place, the breakdown of mesodermic organs is practically of equal importance in determining the mortality of infants with the breakdown of endodermic organs, in the case of the female. This fact, of course, arises because of the heavy mortality of infancy due to failure of the female reproductive organs, a matter which has already been discussed. The curve for breakdown of the ectodermic organs follows substantially the same kind of course in the female as it does in the male. The mesoderm and endoderm lines cross nearly 20 years earlier in the case of females than in the males. This circumstance arises from the fact that throughout life the mesodermic organs play a relatively more important rôle in the determination of mortality in the female than they do in the male.

What reward in the way of useful generalizations may be claimed from the details reviewed? I hope that these facts will have served in some measure to complete and round out in clearer outlines one part of the picture of the general biology of death. It has been shown in what has preceded that natural death is not a necessary or inherent attribute or consequence of life. Many cells are potentially immortal and the potentiality is actually realized if appropriate conditions are provided. Protozoa are immortal. Germ cells are immortal. Various somatic cells, and even tissues have been proved to be potentially immortal by demonstrating in a variety of ways that under appropriate conditions they continue to live indefinitely. This is the lesson taught us on the one hand by successive transplantations of tumor cells, which are only modified somatic cells, and on the other hand by successful culture of many sorts of somatic cells *in vitro*.

Analytical consideration of the matter shows very clearly that why the somata of multicellular organisms die is because of the differentiations and specializations of structure and function which they exhibit in their make-up. Certain cells are differentiated to carry on certain specialized functions. In this specialization they forego their power of independent and indefinitely continued existence. The cells lining the lungs, for example, must depend in the body upon the unfailing normal activity of the cells of the alimentary tract and the blood in

order that they, the epithelial cells of the lungs, may get proper nutrition. If in such an interlocking and mutually dependent system any one part through accident or in any way whatever gets deviated from its normal functioning, the balance of the whole system is upset. If the departure of any part from its normal functional course is great enough to be beyond correction promptly through the normal regulatory powers of the organism, death of the whole will surely ensue.

What I have tried to show in the present paper is a quantitative picture of how the different organ systems get out of balance, and wreck the whole machine. The broad orderliness and lawfulness of the whole business of human mortality is impressive. We have seen that different organ systems have well-defined times of breakdown. Or, put in another way, we see that in the human organism, just as in the automobile, the serviceability of the different parts varies greatly. The heart outwears the lungs, the brain outwears both. But we have further, I believe, got an inkling of the fundamental reason why these things are so. It is broadly speaking, because evolution is a purely mechanistic process instead of being an intelligent one. All the parts are not perfected by evolution to even an approximately equal degree. It is conceivable that an omnipotent person could have made a much better machine, as a whole, than the human body which evolution has produced. He would presumably have made an endoderm with as good resisting and wearing qualities as the mesoderm or ectoderm. Evolution by the haphazard process of trial and error which we call natural selection, makes each part only just good enough to get by. In the very nature of the process itself it can not possibly do anything any more constructive than this. The workmanship of evolution, from a mechanical point of view, is extraordinarily like that of the average automobile repair man. If evolution happens to be furnished by variation with fine materials, as in the case of the nervous system, it has no objection to using them, but it is equally ready to use the shoddiest of endoderm provided it will hold together just long enough to get the machine by the reproductive period.

It furthermore seems to me that the results presented in this paper add one more link to the already strong chain of evidence which indicates the highly important part played by innate constitutional biological factors as contrasted with environmental factors in the determination of the observed rates of human mortality. Here we have grouped human mortality into broad classes which rest upon a strictly biological basis. When this is done it is found that the proportionate subdivision of the mortality is strikingly similar in such widely dissimilar environments as the United States, England and Southern Brazil. It is inconceivable that such congruent results would appear if the environment were the predominant factor in human mortality.

THE DEBT OF MATHEMATICS TO THE CHINESE PEOPLE[1]

By Professor GINO LORIA
UNIVERSITY OF GENOA, ITALY
and Professor R. B. McCLENON
GRINNELL COLLEGE

TO write a satisfactory account of the contributions of the Chinese to the development of mathematics has always been a task beset with peculiar difficulties. These difficulties consist in the extreme uncertainty which the historian always feels as to the date and authenticity of any Chinese manuscript, coupled with the known tendencies of the Chinese people to glorify their ancestors and to exaggerate greatly the discoveries which they had made, in many cases attributing to them ideas and concepts which it is quite impossible that they can in reality have known.

As an illustration of these difficulties, let us mention two interesting examples where results obtained by Chinese mathematicians, and claimed as original discoveries by them, can with little short of absolute certainty be traced back to Greek influence and indeed to the particular influence of the greatest of the Greek mathematicians, Archimedes. First, we find attributed by later Chinese writers to a Buddhist monk Hang a proof that the number which we write 3^{361} is not infinite, but can be expressed either in words or in writing. To do this, Hang introduces a system of "octads," that is, groups of 10^8 successive integers, in such a way that the "first octad" consists of the integers from 1 to 10^8, the second octad of the numbers from 10^8 to 10^{16}, and so on. This scheme obviously permits a simple expression to be found for integers even much larger than 3^{361}, the number with which Hang was concerned. This procedure, as a moment's thought will convince us, is but one of an unlimited number of possible means of accomplishing the same object; and it is precisely the method adopted by Archimedes in his "Sand-reckoner," which makes it seem certain that the Chinese work was inspired by the result previously obtained by the great Syracusan.

[1]This article is based on a communication made to the society "Mathesis" by Professor Gino Loria, and published in the *Bollettino della Mathesis* in April, 1920. Through the kindness of Professor David Eugene Smith the communication came to my hands, and I am glad to take this means of presenting it to the notice of Americans who are interested in the history of science. Professor Loria's communication has been much condensed, and accordingly he is not responsible for the form of this article, but only for its content.—R. B. McClenon.

As our second illustration, we find a remarkably accurate approximation to the value of π worked out by Tsu Ch'ung-Chih in the 5th century. By working with a circle of radius 10^8 (it is significant that this is the same number that had been chosen by Hang as the basis of his system of "octads") Tsu found that π lies between 3.1415926 and 3.1415927. He accordingly suggested a better approximation for π than the familiar 3 1/7, namely 355/113 (which is equal to 3.1415929+). We have here an extension of the results given by Archimedes in his "Measurement of the Circle," and if we accept P. Tannery's[2] emendation of a passage in Heron's *Metrica*, Archimedes had further obtained the result,

$$\frac{195882}{62351} > \pi > \frac{211872}{67441}$$

Writing these values in the form of continued fractions,

$$3+\cfrac{1}{7+\cfrac{1}{16+\cfrac{1}{8+\cfrac{1}{1+\cfrac{1}{60}}}}} > \pi > 3+\cfrac{1}{7+\cfrac{1}{16+\cfrac{1}{31+\cfrac{1}{2+\cfrac{1}{9}}}}}$$

we are led to the approximation $\pi = 3+\cfrac{1}{7+1/16} = \frac{355}{113}$, which could thus have easily reached China along with the other work of Archimedes. And even if we grant that Tsu may have originated this particular approximation for π, it still remains certain that the *method* which he used was not original with him, and it is almost a certainty that he obtained this method from Archimedes's famous work.

These illustrations, with many others of the same kind that might be cited, give rise to legitimate doubts whether in other cases, even where no direct connection can be established with other countries, the Chinese writers did not also receive their inspiration from abroad. These doubts are not quieted when we observe that practically all of the Chinese mathematical works are merely collections of problems, solved by rules which are not demonstrated; so that it is very difficult to determine whether these rules were really understood by the writer

[2]Memoires scientifiques, t. 3, Paris, 1915, p. 149.

or not. What shall we say when we find in the midst of a set of trivial or even nonsensical problems one like the following? "There is a group of objects whose number is unknown; dividing by 3, the remainder is 2; by 5, the remainder is 3; and by 7, the remainder is 2; what was the number?" The author of the collection in which this occurs, Sun Tsu, obtains a solution, 23, by using a method called Ta Yen, which does not differ from that taught by Gauss[3] for solving similar problems in general: and what more significant praise could be given? But as Sun Tsu gives not the slightest indication that he regards this problem as more interesting or valuable than its trivial companions, we may well question his claim to the discovery of Ta Yen.

One of the classical Chinese mathematical productions was the "Arithmetic in Nine Sections," but unfortunately nothing is known definitely as to the date at which the collection took its present form. Parts of it very likely go back to the period before the "burning of the books" (by the emperor Shih Hoang-ti) in 213 B. C. but much of it is certainly of later date. The following interesting and original problem is found in this collection:

"A square city of unknown side is crossed by a street which joins the centers of the north and south sides; at a distance of 20 paces north of the north gate is a tree which is visible from a point reached by going 14 paces south from the south gate and then 1775 paces west. What is the length of each side?"

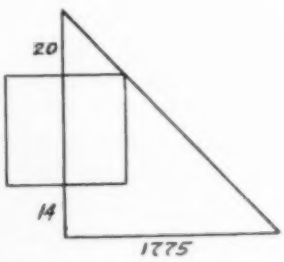


FIG. 1

The Chinese writer gives correctly the equation to which this problem leads, viz., $x^2+34x-2\cdot20\cdot1775=0$, but his statement as to how to solve the equation has probably been corrupted by copyists, as it merely states that the root of a certain expression must be found. As a matter of fact, the only positive root of this equation is $x=250$; which makes it clear that the originator of the problem must have chosen the numbers involved deliberately, so as to produce a simple result.

[3] *Disquisitiones Arithmeticae*, Sec. 32-36.

Whether the originator was a Chinese at all seems questionable, after examination of another problem of a similar kind which is met with in a work composed much later, namely, the "Nine Sections of Mathematics," written in 1247 by Ch'in-Chiu-Shoa. The problem reads:

"A circular castle has four gates facing the cardinal points; at a distance a(=3) to the north of the north gate is a tree, which is visible from a point situated at the distance b(=9) to the east of the south gate. What is the diameter of the castle?" Ch'in says this leads to the equation

$$1x^{10}+7ax^8+8a^2x^6-4(b^2-a^2)x^4-2b^2\cdot 8a^2x^2-2b^2\cdot 8a^2b=0$$

and states that the root is x=9, the length of the diameter.

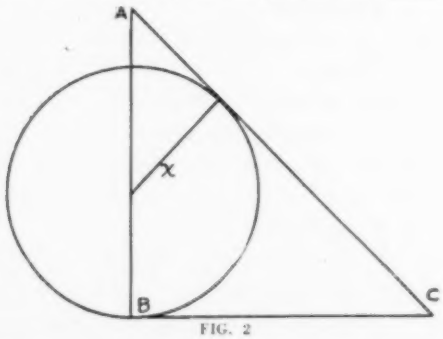


FIG. 2

Before commenting on this, let us solve the problem for ourselves. Thus, taking x as the radius, and expressing the hypotenuse of the right triangle ABC in two ways, we have

$$AC^2=b^2+(2x+a)^2=(b+\sqrt{a^2+2ax})^2$$

from which we obtain $2x^3+ax^2=ab^2$,

an equation enormously simpler than that given by Ch'in. And not only that, but the result stated by Ch'in, x=9, does not satisfy his equation at all! Hence even if there is some copyist's error present, we seem forced to the conclusion that Ch'in did not very fully understand the problem, else he could not have supposed that it required so formidable an equation to solve it. Hence the doubt just expressed as to the Chinese origin of the problem. Moreover, no information whatever is given as to how an equation of this kind is to be solved. Presumably the method was similar to the one used in another case, which is more fully reported by Ch'in; but which also leaves much to be desired in the way of clearness and completeness. This other problem is as follows:

$$-x^4+763{,}200x^2-40{,}642{,}560{,}000=0.$$

"The first figure of the root is seen to be 8" we are told; but how this important fact "is seen" we are not informed. This significant omis-

sion arouses suspicion that the answer may have been known beforehand, as in the case of other problems referred to above. Knowing that a root of the equation lies between 800 and 900, the process known as Horner's method enables us to find a new equation whose roots shall be 800 less; and without going into the details of the computation it is sufficient to say that the transformed equation is

$$y^4+3200y^3+3{,}076{,}800y^2+826{,}880{,}000y-38{,}205{,}440{,}000=0,$$

and this way may be taken to be the meaning of the following table, which Ch'in gives in connection with his explanation of the problem:

8	root
38,205,440,000	absolute term
— 82,688	" of 1st degree
— 30,768	" " 2nd "
— 32	" " 3rd "
— 1	" " 4th "

Barring the omission of zeros, which we must attribute to a copyist's error, this result coincides with the correct one given just above. But we still have too meager information as to the details of the work for us to be able to affirm confidently that Horner's method was known to the Chinese in the 13th century; we can only say that this method, or one practically identical with it, was known at that time, and we must await further evidence before affirming or denying the priority of the Chinese in its discovery.

Biernatzki[4] quotes from Ch'in Chiu-shao another illustration of the method, which however, has been so badly mangled by copyists, that we can not judge as to whether Ch'in was really able to solve the equation in question or not.

It is thus clear that much further investigation will be necessary before this interesting and important question in the history of mathematics, the question as to how much the progress of the science in reality owes to the Chinese people, can be answered with any degree of certainty. It is to be hoped that scholars qualified by knowledge of the language will in the near future enter upon these researches and carry them through to a successful conclusion.

[4]Crelle's Journal, 52.

MANUELITO OF THE RED ZERAPE

By C. M. GOETHE

SHOULDERS wrapped in red zerape, Manuelito, an undersized chunky Mexican, leaned against a weather-stained column of the Guanajuato jail entrance. He has just tilted forward his high-peaked hat to better shade his eyes, when suddenly, taking his cigarette from his lips, he hissed: "The Gringoes." Into those two words was compressed all the race hatred he could contain.

His country's President, Diaz, had welcomed foreign capital. Eager Americans invested heavily in its mines. This caused race friction. In Guanajuato, one American superintendent became convinced his peon miners were "high grading." With two countrymen he went one evening to the tunnel's mouth to meet his outcoming day shift. He knew that the peon, because of years of Spanish misrule, had evolved as a bred-in-the-bone smuggler. Each approaching peon that evening had in his hand a suspiciously heavy kerchief. The superintendent demanded to see the contents of the first miner's bundle. The latter had evidently anticipated such a move. Rather than be caught with stolen ore, the Mexicans treated the "Americano's insult" as a signal to open their characteristic guerilla warfare. Soon they were firing from behind rock piles. A quarter hour later one American was limping home. Beside him walked the superintendent, a flesh wound in his arm. The corpse of one "high-grader" was being carried through the opening of the cactus fence surrounding his adobe home, amid the wailing of his women folk.

The news spread with prairie-fire rapidity. Nearing Guanajuato's outskirts, the Americans were met by the police, arrested, thrown into jail. In those days, government policy caused Mexican jails to offer no inducement to prolonged lodgers. Even food was not provided unless sent in by mother, sweetheart or friend. The American trio was cared for by its fellow exiles of the town. Therefore, hardly had the former spent an hour in jail when three baskets, sent by the American colony, arrived at the jail door.

It was these baskets that had caused Manuelito of the red zerape to hiss: "The Gringoes." The jailer spat at the baskets. Then, overcome by curiosity, he lifted, one by one, their covers. A diabolical grin expanded over his coffee-brown face. One basket contained a day's food for the three men. The second had a similar supply of bottled water, the jail water being notorious for its content of typhoid germs. The third basket had cigars and magazines. Manuelito al-

ready had intentionally isolated his prisoners in, respectively, his North, his South and his East towers. Thus intercommunication was made practically impossible. "Innocentia!" he cried clapping his hands as an additional signal. In high-pointed sombrero, and a single white cotton garment, the barefooted Innocentia appeared. The jailer pointed to the baskets. "One to each Americano" was the laconic order.

For two days one American gorged on three men's *enchilidas* and *frijoles*. The second smoked more cigarettes than ever before. The third, the superintendent himself, a heavy smoker, was without food or tobacco. His wound pained him. He feared a nervous breakdown would come before starvation brought death. But his basket contained only bottled water. It was he who bribed Innocentia to carry a splinter to his downtown friends. Laboriously upon it he had scratched, with a bit of oxidized ore, two words: "Mix baskets." Next morning when the thrifty Innocentia walked through the arched gate, past Manuelito of the red zerape, the stick was concealed in his high hat. That noon the superintendent's basket carried within its wicker walls a welcome mixture of food, water and tobacco. The wounded man heaved a sigh of relief. As he finished his meal, he repeated the Hindu proverb: "Even the Sahibs have not all the wisdom."

In the game of international politics, too, the Saxon, the Sahib of the Hindu, "has not all the wisdom." Nor has our attitude toward our nearest neighbor in Latin America been clearly understood. Turgidity of thought has been increased by certain forces. One of these, powerfully organized and at work on both sides of the border, has labored to generate suspicion, to fan the embers of international hatred.

Because of the suspicion with which much of Latin America persistently has regarded the Saxon Northland, as illustrated in the Guanajuato incident, the work of the group at the Archeological Museum at Santa Fe deserves the attention of every American who is devoted to his country, and who has faith in the noble part his land is destined to take in world affairs. Of all the commonwealths whose stars shine on our banner, probably none has so serious a problem in socializing, in Americanizing, a great extra-racial group as has that state of which Santa Fe is the capital and whose very name, New Mexico, indicates its centuries of attachment to the land of the Aztec.

Santa Fe is approximately 20 per cent. Saxon. The other 80 per cent. is Mexican Amerind. The Mexican element ranges from the illiterate peon of practically all native Mexican stock to the man of nearly pure Castillian blood. Of the latter, some are of that dominant Nordic strain which furnished those remarkable Conquistadores, the old Gothic aristocrats of the Iberian Peninsula, whose blue veins, showing through their fair northern skin, gave rise to the term "*sangre*

FIG. 1. NEW MUSEUM BUILDING SHOWING SANTA FE'S USE OF THE PUEBLO STYLE OF ARCHITECTURE. OUT OF THIS NEW MEXICO'S CAPITAL IS BECOMING THE ONE STATE CAPITAL OF OUR COUNTRY ARCHITECTURALLY TRUE TO ITS INDIVIDUALITY

azul", which we have anglicanized into "blue-blooded." These Latin folk of New Mexico, blue-blooded or swarthy, Castillian or Aztec, are bound to the Motherland across the Rio Grande by ties, social, political, and what is always most deep-seated of all—religious. To break down the barriers of race hatred, race suspicion, and race mistrust between the 20 per cent. of Saxons and the 80 per cent. Latin-Mexican-Amerinds, to lead both to learn to appreciate and respect the good in the other and to know that this good is far more important than racial differences of opinion, was, and is a task requiring no little tact, no little nice discrimination.

The founders of the New Mexico Museum at Santa Fe did not hesitate to commence work when the vision of these possibilities came to them. While their basic interest in creating their museum was of course the archaeological one, they still kept before them this dream of making it more than a mere museum, more than even a community recreation center. They glimpsed it as a laboratory within whose crucibles they, twentieth century alchemists, might discover, in experimenting with Saxon, Latin, Amerind, that which was to be more desired than fine gold—interracial sympathy and good will.

The old Santa Fe Palace, facing the plaza, built on the walls of an ancient pueblo, and since occupied by Spanish, Mexican and American governors, was their first laboratory. Here commenced the foundational experimenting,—that with the Saxon group. Three subdivisions

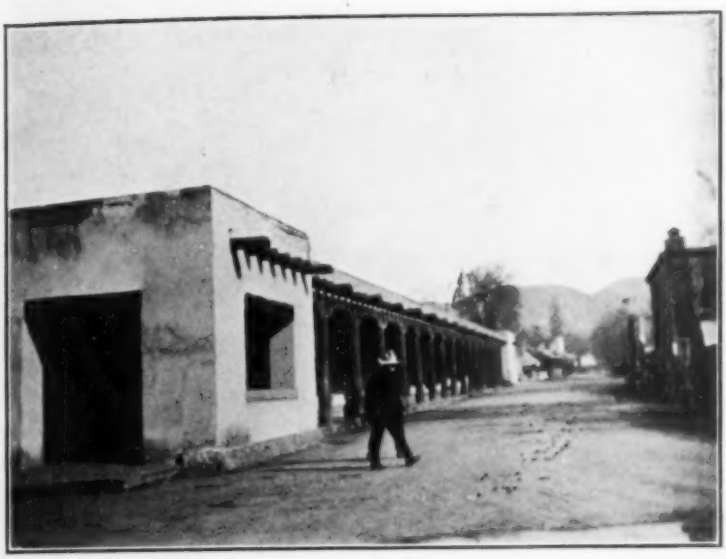


FIG. 2. THE OLD PALACE OF THE GOVERNORS, HOUSING ANOTHER PORTION OF THE COLLECTIONS

of this Saxon group were perhaps most easily handled. These were the Women's Club, the Chamber of Commerce, the State Government.

The average Western Women's Club is known for its progressiveness. In their struggle for the suffrage, Western women have evolved with a capacity for moulding civic ideals. In Santa Fe their interest in the museum community center, once aroused, has continued constant. They make it *their* center. One of its halls, for example, became the center for Red Cross work during America's struggle for world democracy. Historically doing this was consistent, because in the plaza opposite is the spot where General Kearney, in raising the American flag, gave Santa Fe's Latin citizens their first message of American democracy. The charmingly appropriate furniture of the museum room wherein these women met is evidence that the museum group discovered that there is a New Mexican Colonial, as well as a New England Colonial style. Rawhide was strung while yet green. Native woods were skillfully used in chest, chair, panel and picture frame. Reveries of history made when the Americans cut short the rule of the Mexican governors who taxed each passing prairie schooner $500, mingled thus with Red Cross workers' thoughts of history then-in-the-making.

The Chamber of Commerce was also brought into the experiment. Most Chambers can be accurately judged by their slogans. Santa Fe's is "America's most interesting 50-miles-square." The Chamber's slogan, based upon the museum's activities, has crystallized into it the

FIG. 3. DWELLING HOUSE IN SANTA FE IN PUEBLO STYLE

daring and resourcefulness that is characteristic of life on trail and in desert. An aesthetic slogan? Yes. Yet it has conclusively demonstrated that the aesthetic, the clean in civics does more than gratify a human hunger—it pays dividends commercially. The Santa Fe-Taos artist colony is an example of such commercial profit. This community is largely an outgrowth of the museum's activities. Some of the artists are housed on the museum grounds. All cooperate with the museum staff, whose research in turn makes for historical accuracy in the artists' work. The Museum's art gallery is expanded by loan collections, also by artists' exhibition. The 30,000 tourist visitors, many of them art-loving, not a few able and glad to buy, make a welcome market for their canvasses. In 1917, a war year, the artists' output is said to have been $175,000. Assuming $800 yearly as a then average annual wage, this equals the earnings of a factory of 218 hands. The value of the artist group as a community asset, however, is not to be measured by the factory standard. Like Los Angeles, Copenhagen, also Geneva, Santa Fe thus shrewdly has been "corralling" as residents, to use the expression of her red-kerchiefed cowboys, those citizens eugenically fit. Single individuals of this artist type are, with their keen imagination and foresight, in their resulting contribution to community life, particularly in matters of education, worth more than several smoke belching chimneys.

Thus two Saxon groups, the Chamber of Commerce, as well as the Women's Club, were thus skillfully aligned to back the State government in doing what the progressive official is always ready to do with

FIG. 4. ONE OF THE "PYRAMID CITIES OF TAOS," SHOWING THAT PUEBLO ARCHITECTURE HAS BEEN MADE THE BASIS OF THE ARCHITECTURE OF THE MUSEUM AND OTHER BUILDINGS IN SANTA FE

such organized approval, i. e. the making of reasonable appropriations. Thus New Mexico has already *done* that of which the city planning groups of most other American States are as yet but *dreaming*. New Mexico, recognizing the wisdom of the European method, therefore made the solution of Santa Fe's City planning problems a matter of state concern. Its legislature studied the plan of the museum as a forceful example of what already was coming to be called the "Santa Fe" style of architecture. The statesmen said, "We want to own a part of this." Thus state appropriation was added to money from municipal and from other sources. All these funds went toward crystallizing into this community-center-structure the Santa Fe spirit. Space does not permit telling how community ideals have been shaped, other than to suggest that Santa Fe bids fair to become the first American capital to be architecturally true to its own individuality.

Thus into the museum crucible were brought the three elements, feminist, commercial, political, composing the leadership of Santa Fe's 20 per cent. of Saxon citizenry. Eighty per cent. remained. This 80 per cent. was Mexican. This group was high-strung, sensitive. They were proudly conscious of their own culture. They knew only too well that the Saxon had conquered their leaders in battle—that he had not always refrained from showing that he did not always think in the way in which they did. The task was to bring these folk into the melting pot, to soften and eliminate mutual race hatred, to make each Mexican

FIG. 5. PUEBLO INDIAN, WITH OVEN IN THE BACKGROUND

Amerind understand the museum was also his, that, to make it a real community center, their glad use of it was also essential.

Perhaps the best way to tell how this was accomplished with these folk, is to briefly refer to the museum chapel, and to the Mexican pastoral plays, which have been presented therein. To grasp the breadth of this success our thought must run back to medieval Europe. The miracle plays of that period have persisted longest in that conservative environment which, characteristic of Spain, is even more so of her colonies. It was not an accident that the last faggots of the Inquisition were ignited in Mexico City. Buttressed by this conservatism in Mexico, also in the Santa Fe countryside that formerly floated Mexico's banner of eagle, rattlesnake and cactus, there have survived, always still in unwritten form, those miracle plays which Europe, which even Spain, had almost forgotten. There is, therefore, no better evidence that the intensely conservative Latin New Mexican has accepted the spirit of the Museum center than his rendition, in the Museum community-center chapel, of such plays as "Los Pastores," (The Shepherds). This chapel hall takes the outward form of one of his missions. Its ceiling

FIG. 6. ANOTHER EXAMPLE OF PUEBLO ARCHITECTURE

is of aspen trunklets carried by burros from the canyons that dent his mesas. They duplicate those of these self-same missions. Its floor is of stone flags from the mountains he had, from their sunset hues, reverently called "Sangre de Christi" (Blood of Christ). Its beams are hand carved and lovingly colored in the old way by his neighbors, the Indian artisans. What setting could be more fitting?

The problem of the residual element in the crucible, the Pueblo Amerind, was vastly more complicated. The American Indians around Santa Fe are largely Tewa, belonging to what we commonly call the "Pueblos." The vicinity contains evidences of their wonderful culture of the long ago. Long before Charlemange was pushing the frontier of his empire to where the then rude Saxons afterward built their capital, Dresden, the ancestors of these Tewas, with knives chipped from lustrous black obsidian, had carved their cave dwellings out of the friable, faded pink volcanic tufa that formed the walls of the basalt-capped mesas. Here this people had evolved their wonderful culture. To-day their descendants live in such pueblos as the Sky City of Acoma, or the twin pyramid towns of Taos, astride the little stream that cas-

FIG. 7. PUEBLO FAMILY GROUP

cades down from 13,000 foot snow-capped giants forming their background. The Tewa culture of these folk deserves more respect than the Saxon is wont to show. In many things the Amerind anticipated his pale-faced brother. We are proud of our democracy born of our long struggles. There is evidence that the Tewa had a comparatively pure democracy centuries before one of the French Bourbons had cast into the bronze of his cannon, the dogma, "Cannon—the last argument of Kings." Apartment houses? When cattle lifting was a gentleman's occupation along the Scottish border, the Tewa had not only built, but almost no longer remembered that he ever had occupied community structures which the Santa Fean volubly will tell you "had twice as many rooms as the Waldorf-Astoria." Vocational training? In these forgotten rooms, chiselled farther back in history than when Crusader Kings were struggling through the blistering sands toward Jerusalem, raven-haired mammas, between their grinding of blue corn meal on stone metates, trained little folk for the pottery making wherein they were to record their epics—by toy models—perfect in design, some of which may to-day be seen in the museum. Recreation centers?

In the Kivas of the Tewa were done much of the work now done by the Y. M. C. A. This was more centuries before than have elapsed since Luther nailed the Theses to a certain German door and commenced the protestant reformation.

These Tewas, who rightfully have pride in their culture, still live to-day in the valley of the Rio Grande. The accumulated experience of the ages has been handed down, as was the ancient Greek epic, from father to son. These Pueblo Amerinds are deeply religious. No venture is undertaken without prayer to Those Above, generally with the scattering of the sacred Corn Meal. Poets to their fingertips—deeply conservative—highly sensitive—what has been the contact of the Saxon with them?

Two examples suffice as to the extremes: An Illinois woman visits a pueblo. She goes to the first house, saying "I want a guide." She holds out a gold piece. The bargaining instinct arises in the man. He shows a few things to the woman. "Now, I want to see the inside of one of the houses up those ladders." "Not until you pay me five dollars more." She pays it. The Amerind has ten dollars for a half hour's work. The woman with a shrug of the shoulders remarks "I never give anything at home to 'charity'. I have much. They have little. It does not hurt me." But an injury has been done to the Amerind. He has acquired a new standard as to what work should be exchanged for American gold.

A second example as to the other extreme. An Arizona trader wants a blanket upon which an Indian woman in one of the district settlements has worked for months. He knows her need for money. They bargain. The blanket will bring him $85. He spreads out in silver quarters, coins totaling $4, then $5, $6, $7. She yields to the arguments of the exploiter. He clears, for a couple of hours work, a profit many times the amount which she received for weeks of labor.

The museum, with the spirit of true community service, has become the real friend of these Tewas. It has recognized alike the danger of the crafty trader exploitation, of thoughtless tourist pauperization. It has, therefore, among other things, opened a pottery exchange at the museum community-center. It encourages some of the Indian artisans to work even within its patios. This brings an addition of local color to the street scenes which has a chamber-of-commerce value, reflected in hotel income. Indian as well as customer is insured a just price. But, above all, it holds the Pueblo Amerind true to the ancient art. It has stopped careless moulding, careless decoration, careless firing. More than all, by pressure, tactfully applied, it has eliminated such intruded designs as locomotives and automobiles from a creation that was once, at the same time, both a poem and a prayer.

Out of this loyalty to the best in the red man's ancient culture has

grown mutual confidence, at times even real affection, between Saxon and Amerind. In the chapel, also, sometimes in the soft moonlight of the museum patio, the Tewa now presents his wonderful dance-dramas, such as the Green Corn Dance of his delight-makers. This he does with a gladness, with a commendable freedom from commercialization. Knowing the sympathetic interest of the onlooker, these dance dramas are acted with the same deep religious fervor that anciently accompanied them in the plaza of his native pueblo.

The chapel door is ajar on museum night. Peeping through, there is seen a "Fireplace Party." The listeners are from all three groups. There is a club woman whose ancestors were nobles under the Great Charles of Spain. There are other club women. One is a Daughter of the American Revolution, proud of her F. F. V. ancestry. That Pueblo Indian boy in front is the one who painted the pictures that the blue-eyed speaker has been using. The latter is Saxon. He is telling fairy tales to the wide-eyed listeners. They are not stories of the lands of his Teutonic forebears, of gloomy forests in the days of Woden, and of Thor, of chimney-resting storks, of fairy princes with whom the wide-eyed children in the flickering firelight have no real contact. The blue-eyed man proceeds with tales of the long ago in Cliff-dweller Land, of the things Santa Fe's children knew, of the yucca of the browned desert, whose leaves went to a "chewing bee" when willing boys thus separated the sugarly pulp from the much-needed fibre. Tales, too, the Saxon tells of the pottery, shards of which, with designs of clouds, of rain, of eagles, are familiar to every New Mexican lad who roams the mesas. There are stories of hunting wild turkeys in the stone age. Hardly a child is present who has not searched for and found at least one jewelled arrowpoint of these softly-treading huntsmen. Santa Fe's children, Saxon, Latin, Amerind, through such fairy stories, are being taught, at the levelling museum-center, not only nature-wisdom and desert folklore, but they are simultaneously absorbing interracial respect. They are coming to appreciate, like the American of the Guanajuato jail, that "the Sahibs have not all the wisdom,"—that the other fellow, even Manuelito of the red zerape, can strike back, that his good will is more to be desired than his hatred.

THE MENTAL STATUS OF THE AMERICAN NEGRO

By GEORGE OSCAR FERGUSON, JR.
UNIVERSITY OF VIRGINIA

A FEW years ago the speaker of the lower house of a state legislature, in delivering the annual address before a college alumni association, chose as his theme the education of the Negro. He argued that the Negro as a race is mentally incapable of any real participation in modern civilization, and that the attempt to educate Negroes should therefore be abandoned.

But at a recent meeting held to consider race relationships in the South, a prominent publicist, pointing out the great progress made by the Negro in this country in the space of two generations, gave it as his opinion that no race could have come so far in so short a time without inherent capacity for civilization equal to that of any other people of history.

Between these extremes lie the views of the great majority of thoughtful students of the problems presented by and confronting the Negro race in America. The intellectual ability of many Negroes is indubitable. The apparently unchangeable stupidity of many others is also indubitable. Generalizing from contact primarily with gifted or with dull representatives of the race, observers have been led to conclusions favoring one extreme view or the other. But in the main they seem to have taken a middle ground to the effect that, while Negroes are often very capable, the general level of intelligence among the masses of the race is considerably below that of whites. That this alleged racial difference can not be removed by education is probably taken for granted, since it is held to be hereditary.

In view of the crucial importance of native intellectual ability for civilized attainment of any sort, it seems to be worth while to summarize the information at present available concerning the intelligence of the Negro as compared with that of the white man. Only through careful, painstaking study and experiment and the gradual development of a scientific psychological technique can the haze of debate and belief be replaced by established knowledge. As yet comparatively little of a scientific nature has been accomplished in investigating the mind of the Negro. But such facts as there are should be incorporated into the thought which is the basis of our action.

By a man's intelligence is meant his ability to think quickly and accurately, to obtain an insight into new problems, to comprehend sit-

uations, to learn easily, to arrive at and apply conclusions, to be mentally alert. Dullness or stupidity is the absence of these abilities. An intelligent man "catches on", apprehends the meanings and significances of things, has "sense" and can meet the demands of life. A dull or stupid person lives in a world in which things and people are relatively simple and arbitrary; he does not know or inquire into the hows and whys of affairs; he can perform routine tasks, but relationships and possibilities are so lacking in his apprehension that he can not meet new situations successfully or devise new ways of acting. To intelligence the complex meaningfulness of life and its institutions is apparent; stupidity cares nothing for such things because it knows nothing of them.

Obviously a man may have excellent intelligence but poor sense organs and power of bodily movement. Keenness of sight, hearing, taste or smell is not necessary to intellectual power, nor is muscular ability. That part of a man's body which determines his intelligence is the cortex or outer rind of his brain, where are found the intricately branching nerve cells and fibers that constitute his "grey matter". The sense organs of Negroes are as efficient as those of whites; the Negro's muscular system is as efficient as the white man's. If there is a difference in intelligence between the two races, its physical counterpart must be looked for in brain differences.

The brain of the average Negro weighs three or four ounces less than the brain of the average white man. But the brain of the average white woman also weighs three or four ounces less than that of the average white man. And while the brains of eminent men, on the average, weigh more than the brains of men in general, yet many men of inferior ability have brains much heavier than those of men of marked attainment, and many men of eminence have brains of much less weight than that of the average tramp. It is therefore evident that brain size does not determine intelligence. And while there are certain differences in the anatomical proportions of the brains of whites and Negroes, such differences are not great and their significance is not well established. Differences that may exist in the constitution of the brain cortex, with which intelligence is most intimately connected, can not be distinguished by the methods of investigation available at the present time.

While there is thus no difference of well established significance between the brains of the two races, it is not unreasonable to suppose that the great differences in physique and feature between typical Negroes and whites are accompanied by correspondingly important neural differences. Unless there be such corresponding neural differences the situation is probably unique among biological phenomena.

The obvious method of attack upon the question of the Negro's intelligence is by means of mental tests. In recent years the general

nature of such tests has become familiar to most people. In general, they aim to measure native or natural intelligence, as distinct from the results of education or training. There are many kinds of tests and they differ greatly in the success with which they accomplish their purpose. But on the whole, when skilfully used, they undoubtedly afford an index of mental capacity vastly superior to unscientific judgments arrived at even after long acquaintance with the persons tested. There have been about a dozen trustworthy investigations of Negro mentality, nearly all of them made within the last decade. And the use of intelligence tests in the army has furnished an unexampled opportunity for psychological study of the Negro soldier.

Before the results of the tests are given, reference should be made to what is probably the best simple method of expressing the relationship between the abilities of groups. The distribution of ability among the individuals of any large and homogeneous group conforms to a well established law. Most of the members of a group are clustered closely around the average, and as the extremes of ability are approached the number of individuals becomes constantly smaller. But the extremes are not exceptions; they are normal variants from the group average, and their number and the amount of their divergence are the same both above and below the average. Thus 50 per cent. of the members of a group equal or exceed the average of that group. Two groups have the same ability if 50 per cent. of the individuals in one of them equal or exceed the average of the other. But if only 10 or 25 or 40 per cent. of group A equal or exceed the average of group B, then group A is inferior to group B. This method of comparing whites and Negroes affords a constant reminder of their "overlapping" in ability and enables us to state the results of different tests in the same terms.

The results of the investigations of whites and Negroes by means of tests have all pointed in the same direction. When Negro children of a given school grade or a given chronological age are compared with white children of the same grade or age, they fall below the intellectual standard of the whites. In the elementary school grades only 20 or 25 per cent. of Negro children equal or exceed the average score of white children. But in high school 30 or 35 per cent. of the Negroes equal or exceed the average white score. That the Negroes do better in the upper grades than in the lower when compared with whites is doubtless due to the fact that a much smaller proportion of Negroes than of whites is found in the upper grades; the Negroes in the upper grades are the selected few of their race to a greater extent than are the whites in the upper grades. It is rarer for a Negro than for a white child to go to school at all; it is much rarer for him to reach high school. This is amply demonstrated by the statistics showing the

school attendance of the two races. And of course it is well recognized that elimination from the successive grades of the school system bears, in general, most heavily upon those pupils who have least capacity, and leaves in the upper grades those in whom ability is greatest. Negroes in the graduate or professional schools of universities probably have as great ability as the average white student there. But the Negroes are far fewer in number.

When the great unselected masses of Negroes in the army were compared with equally unselected masses of whites, the difference between the races, as revealed by the army intelligence tests, was found to be greater than it is in the schools. It was so great, indeed, as to lead to the supposition that the tests were unfair to the Negroes. There were separate tests for literates and for illiterates. The standard of literacy employed was the ability to read a newspaper and to write any sort of letter. Only one-third of the Negro drafted men qualified as literate under this standard, while three-fourths of the white drafted men qualified as literate. On the test for literates, only between 5 and 10 per cent. of the total group of literate Negroes equaled or exceeded the average score of the whites. When the comparison included only men who reported the same number of years of schooling, between 10 and 15 per cent. of the Negroes equaled or exceeded the average score of the whites. On the test for illiterates, the average white score was reached or surpassed by between 10 and 15 per cent. of the Negroes.

This disparity between the scores of the two races is almost certainly due in some measure to the difference in the amount of their education. The tests, and particularly the test for illiterates, were designed as measures of native capacity as opposed to the influence of schooling. But even the handling of a pencil, which the tests required, was probably a greater handicap to the Negroes than to the whites. This supposition is borne out by the results of the widely known Stanford-Binet test, which was employed to examine thousands of drafted men. This is doubtless the most reliable of all intelligence tests; it is adapted to measuring all degrees of ability, from feeblemindedness to such intellectual capacity as will enable a man to do high grade work in a university; and its results are demonstrably free from any considerable educational influence. On this test, between 20 and 25 per cent. of the Negro recruits equaled or exceeded the performance of the average white recruit. And this is everywhere regarded as one of the best indexes which we have of the relative intelligence of the two races.

But even the Binet test, like nearly all of the others which have been used to measure the intelligence of Negroes, requires, in large measure, the mental manipulation of the verbal symbols of ideas. Very few tests have required thinking in terms of concrete objects. Of course the highest type of intelligence is verbal and symbolic. But Negroes, as a race, live primarily in a world of material things and have less

experience than whites in dealing with the world of words. This in itself may be due to an original racial difference; but it may also be due to social conditions. And it may be unfair to expect Negroes to compete on even terms with whites in dealing with words rather than with things. A few tests involving the handling of concrete materials have indicated that Negroes do somewhat better in them than in the more linguistic tests. It seems to the writer that this should be taken into account in estimating the mental difference of the races, and that probably the safest and most reasonable expression of the relative intelligence of whites and Negroes is that approximately 25 per cent. of the latter equal or exceed the average of the former.

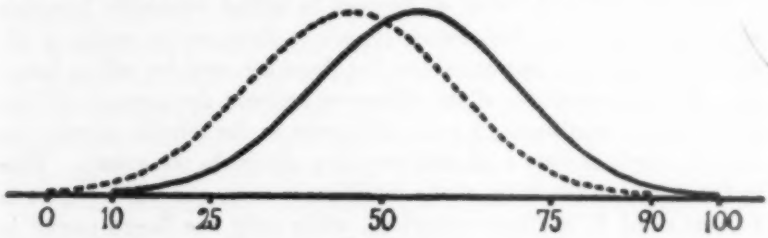


FIG. 1

The diagram exhibits this relationship. The solid curve represents the distribution of ability among whites and the broken curve represents the distribution of ability among Negroes. The curves are drawn in accordance with the law of distribution of individuals in a group, and the relationship between them indicates the relative intelligence of the two races. The figures on the base line are arbitrarily chosen and are intended only to facilitate comparison of the curves. Zero represents the ability of the lowest idiot; 100 represents the ability of the highest genius. The range of ability among the whites is thus indicated as from 10 to 100; among the Negroes it is indicated as from 0 to 90. The height of the respective curves above the base line shows the proportionate number of individuals in the groups at any point on the scale of ability. The average of the whites is approximately 55, while the average of the Negroes is approximately 45. We may express the difference between the averages of the races by saying that it is about one-fifth of the difference between the average white man and the lowest idiot, or one-fifth of the difference between the average white man and the highest genius. As an indication of the remarkable validity and usefulness of the law of group distribution, it may be remarked that Sir Francis Galton, long before the advent of intelligence tests, arrived at approximately this same conclusion as to the average capacities of whites and Negroes by studying only the geniuses of each race, and inferring from their relative abilities the relationship of the races as wholes.

From the diagram it may be computed that approximately 25 per cent. of the Negroes equal or exceed the average ability of the whites, and that approximately 25 per cent. of the whites have ability as low as or below the average ability of the Negroes. In other words, the level of ability reached by half of the whites is reached by only one-fourth of the Negroes, and only one-fourth of the whites are below that level of ability which is the upper limit of half of the Negroes. In passing up the scale from the average to the highest ability, it is evident that the proportion of Negroes to whites constantly decreases until the point is reached, above 90, where there are no Negroes at all. And in passing down the scale from the average to the lowest ability, it is evident that the proportion of Negroes to whites constantly increases until the point is reached, below 10, where there are no whites at all. There are very few Negroes above 75; there are very few whites below 25. The comparatively slight difference between the average abilities of the two groups makes a great difference in the relative proportions of individuals of very high and very low ability in the groups. Thus in the army, on the basis of the intelligence tests, one white recruit in 20 was rated A, or "very superior", while only one Negro recruit in 400 received this rating. And the proportion of feebleminded individuals among the Negroes was much greater than among the whites.

But it should be noted that while the proportion of Negroes in the higher grades of intelligence is small in comparison with the proportion of whites, there are yet Negroes in the higher grades. Few whites have greater intelligence than the highest of the Negroes, and few Negroes have less intelligence than the dullest of the whites. This fact should not be lost sight of in considerations of the status of the Negro. Nor should it be allowed to obscure the differences that exist between the two races.

Since there is such great overlapping in intelligence between whites and Negroes, it is obviously impossible to make a satisfactory statement of the difference between them in terms of the difference between any two classes of the white population. The ability that is typical of practically any large group of whites is also found among Negroes. And there is great variation in ability among any large group of whites, such as an occupational class. It is probable that there are no two large occupational classes which differ so greatly in ability that there is no overlapping between them. But while this is true, it is yet possible to state, although only suggestively, the difference between the *average* Negro and the *average* white in terms of the difference between the *average* abilities of certain occupational groups of whites. Thus it is probable that the difference in intelligence between the professional and the clerical classes of whites, or the clerical and the semi-skilled labor classes, is not far from equivalent to the difference between

whites and Negroes as groups. It is probable that the intellectual difference between the average policeman or fireman and the average doctor or lawyer, or the difference between the average street car employee or salesgirl and the average elementary teacher or small business man, or the difference between the average tramp and the average groceryman, is not far from equivalent to the difference between the average white and the average Negro. As skilled differs from unskilled labor in intelligence, it is probable that the average white man differs from the average Negro. Or the difference between the races may be expressed as roughly equivalent to the difference between the average white man and unskilled labor, or the difference between the average white man and the clerical classes.

In considering the mental capacity of the Negro, up to this point no account has been taken of the feeling and dynamic sides of mental life as distinguished from the intellectual. It is a common opinion, based upon observation and experience, that the Negro differs more from the white in such traits than in intellect proper. His emotions are generally believed to be strong and volatile in their manifestations; instability of character is ascribed to him; it is contended that he lacks foresight and persistence, that he is improvident and content with immediate satisfactions, that he has small power of seriôus initiative and that he lacks ambition. Along with high emotionality and instability of character, defective morality is ascribed to him, and the statistical records of crime and sexual immorality are cited in this connection.

At the present time it is impossible to make adequate measurements of these important human traits. If the Negro differs from the white in his manifestations of temperament and character, such differences may be due to the total circumstances of his life rather than to the intrinsic nature of his disposition. It may be that his social condition would produce his alleged characteristics, even if he were possessed of the psychic nature of the white man. On the other hand, it may be that the emotional and dynamic qualities ascribed to the Negro are due to his demonstrable intellectual deficiency, rather than to the inherent strength of his active tendencies. Pronounced and changing expressions of emotion, improvidence of character and a tendency to immoral conduct are not unallied. They are all due to uncontrolled impulse. And a deficient development of the more purely intellectual functions may produce all three. Where the implications of ideas are not apprehended, where thought is not lively and fertile, where meanings and consequences are not grasped, the need for the control of impulse will not be felt. This is strikingly evident in cases of feeblemindedness. And the supposition that the impulsive life of the Negro is explainable on this basis is reinforced by the common observation

that the lower levels of intelligence among white men are accompanied by traits of character not unlike those ascribed to the Negro. It is among the intelligent classes of whites that uprightness of conduct, self control and foresight in the management of affairs are most generally found. And this is doubtless also true of the more intelligent classes of Negroes.

The term Negro is generally used to refer to all descendants of black stock in America, without regard to the presence of individuals of African lineage other than the true Negro. It is also generally used to refer to the whole colored population, without regard to the presence in it of individuals of mixed white and Negro blood. This paper has followed the general usage. But while little is known concerning the influence of ethnic stocks other than the true Negro, the presence of the so-called mulatto in the colored population complicates all statements of Negro capacity. The term mulatto is employed here to refer to Negroes with any perceptible trace of white blood, regardless of its amount. This is the usage of the United States Census, which states that in 1910 mulattoes constituted approximately one-fifth of the colored population of the country. Since there is an increase in the proportion of mulattoes from decade to decade, due of course in large measure to intermarriage between mulattoes and "pure" Negroes and among the mulattoes themselves, it is probable that they now constitute about one-fourth of the Negroes in America.

The proportion of mulattoes among the colored population is considerably higher in the cities than in the rural districts and it is considerably higher in the North than in the South. It is also considerably higher in the school population than in the colored population at large and it is considerably higher in the upper grades of the school system than in the lower. If this educational distribution of mulattoes were true only for the country as a whole or for entire states it would not be significant, since educational advantages are greater in the North and in the cities, where the greatest proportions of mulattoes are found. But it is true where the educational advantages are the same for all classes of Negroes, as in a given city. And of colored children of a given degree of educational attainment, as those in the same school grade, the mulattoes are generally younger than the pure Negroes. These facts as to the distribution of mulattoes would therefore seem to indicate that they have greater ability and energy than pure Negroes. They are apparently more ready to perceive and to take advantage of the reputed opportunities of Northern and urban life. And they are apparently more ready to perceive the advantages of education and to make progress in school work.

The supposition that mulattoes have greater ability than pure Negroes is borne out by the results of mental tests. It is doubtless true that skin color is not an accurate index of the amount of white

blood in an individual. But when considerable numbers of Negroes in the schools are classified on the basis of skin color and compared age by age or grade by grade, it is found that those of lighter color obtain higher average scores on intelligence tests than those who are darker. Where there have been as many as four groups in the classification, corresponding roughly to pure Negroes, Negroes three-fourths pure, mulattoes proper and quadroons, it has been found that the average scores of the lighter classes were successively higher than those of the darker. And when several thousand Negroes in the army were similarly classified, the results of the army intelligence tests showed that the Negroes with the greater amount of white blood, as indicated by skin color, obtained uniformly higher average scores on a given test than those with less white blood. A summary of the test results indicates that roughly 20 per cent. of the pure Negroes, 25 per cent. of the Negroes three-fourths pure, 30 per cent. of the true mulattoes and 35 per cent. of the quadroons equal or exceed the average score of comparable whites.

It is worthy of note in this connection that when the Negro recruits in the army were classified on the basis of literacy, it was found that the percentage of mulattoes among the literates was approximately twice as great as among the illiterates, and that this was true when both literates and illiterates were from the same draft area. Indeed, the difference in skin color between the literates and the illiterates was such that after the illiterates had been eliminated from a company the complexion of the group remaining was noticeably lighter to casual observation. It is also worthy of note that the Northern Negroes obtained higher average scores on a given test than the Southern, and that the urban Negroes obtained higher average scores than the rural.

While mulattoes as a group have greater intellectual capacity than pure Negroes, the overlapping in ability between the two classes is very great. It is greater than the overlapping between mulattoes and whites, since the greater number of mulattoes have a preponderence of Negro blood and since probably a majority of them are descendants of inferior elements of the general population. But even a slight difference in capacity between Negroes of pure and of mixed blood would produce a considerable difference in the number of individuals of great ability in the two classes. According to the relative size of the total groups of mulattoes and pure Negroes, there should be three or four times as many persons of marked attainment in the latter as in the former. But the difference in capacity between the two groups leads to the supposition, which is supported by a not unfounded general belief, that there are at least as many mulattoes as pure Negroes among the leaders of the race in this country. The matter can not be conclusively decided, however, because of the lack of satisfactory lists of col-

ored men of attainment and because there is no sure indication of the amount of white blood possessed by individuals included in such lists as we have.

It is not unlikely that the presence of the mulatto may affect the interracial relationship in America. His presence will tend to raise the standard of colored achievement. But it may also tend to increase race friction. The mulatto thinks and feels more nearly as does the white man, and he is therefore probably less content than is the pure Negro with a position of racial subordination. And the proportion of mulattoes among the colored population will undoubtedly continue to increase. There is no evidence for the opinion sometimes expressed that the death rate of mulattoes is higher than that of pure Negroes. On the contrary, there is evidence that the colored professional classes, which contain a very high proportion of mulattoes, have a lower death rate than the race as a whole.

The mental difference between whites and Negroes in general indicates that there should be a difference in the organization of the schools of the two races. The public elementary school course, both North and South, is adapted to the ability of those white children who are most nearly average in capacity. But since only the most capable of the Negroes, roughly one-fourth of the total number, equal or exceed the average of white ability, it is unreasonable to expect Negroes as a group to make satisfactory progress in the public schools as now organized. That they do not make satisfactory progress is well known. Much of their lack of success is due to poor attendance and to unfavorable school and home conditions. These adverse social factors are found particularly in the South, where there are separate schools for the two races. But even in the North, where compulsory education laws obtain and where the same schools are attended by both races, the amount of retardation among colored pupils is far greater than among white. The psychological backwardness of colored children is everywhere paralleled by their educational backwardness. It would more nearly accord with all known facts concerning the intellectual ability of the Negro, if the elementary schools for colored children were so organized as to allow them an additional year for completion of the course. In a number of school systems for white children the grades are now so arranged that an additional year is allowed the slower third or fourth of the pupils. This arrangement for the slower white pupils should probably be made the basal plan for colored schools.

The content of the course of study for Negroes should be determined by social factors rather than by psychological. But in this connection it may be noted that the Negro, when compared with the white, seems to have relatively greater capacity to deal with the concrete, the

tangible and the practical than with the abstract, the symbolic and the theoretical. He is highly capable in sensory and motor capacities and in native retentiveness; his shortcomings are logical or rational and more purely intellectual. He is well equipped for manual and industrial training and for acquiring the simpler skills. It is a common observation of teachers that colored children excel in handwriting and in rote memory work. It would seem that the nature of the mental equipment of the Negro lends sanction to the movement to render his schools less literary and "cultural" and more "practical" and vocational.

But since very able colored persons are found in every large group of Negroes, though the proportion of such individuals is much smaller than among whites, opportunities for advanced and professional education should be open to them. The widely held doctrine that the Negro's mental growth ceases at adolescence finds no sanction in experimental studies of his ability. And there is no reliable evidence that the variability of Negroes above and below their racial type is appreciably less than the variability of white men.

Psychological study of the Negro indicates that he will never be the mental equal of the white race. But the Negro in America is capable of great progress. Conditions in various small Negro republics, such as Haiti, Santo Domingo and Liberia, are frequently cited as evidence that the race is incapable of developing a high degree of civilization, and such arguments are not without their value. But in America the colored population is larger than in any of the Negro republics, and the progress of a group depends upon its size as well as upon its average capacity. The larger group will produce more individuals of great ability, and such individuals furnish ideas and inspiration for the whole group. And in America the Negro is in much closer contact with the white race than he is in the isolated Negro states. This contact gives him the advantages of white encouragement, achievement, example and control, and enables him to appropriate to his own use the products of white genius. Races or nations between which there is free intercommunication make greater progress than do isolated peoples, since the results of the ability of each race are more readily taken over and incorporated into the life of the other. It is therefore reasonable to expect the Negroes of America to reach a higher level of attainment than those of their race who are differently situated, even though the native ability of the Negro be everywhere the same.

SOME EARLY THEORIES REGARDING ELECTRICAL FORCES—THE ELECTRIC EMANATION THEORY

By Professor FERNANDO SANFORD

STANFORD UNIVERSITY, CALIFORNIA

SINCE our present electrical theories have arisen from earlier theories by modifications made necessary by later discoveries, any clear understanding of our present view-point makes it necessary to know the steps by which it has been attained. It is the purpose of this paper to discuss the opinions regarding the nature of electrical action which were held by some of the early investigators who were most influential in determining scientific opinion.

The origin of our knowledge of the attraction of rubbed amber for other bodies is lost in the obscurity of the past, but no attempt to explain this striking phenomenon in scientific terms seems to have been made until Dr. William Gilbert published his famous treatise, *De Magnete*, in 1600. Gilbert showed that the power of attracting other bodies could be developed in many substances besides amber; but he learned of no other property of electrified bodies except this attraction for other bodies. This is, accordingly, the only fact which Gilbert's electrical theory was called upon to explain.

Gilbert proposed a true physical theory to account for this fact. He definitely rejected any possibility of action at a distance, and assumed that electric and magnetic attractions must be brought about by means of some intervening medium. Thus he says:[1]

> For as no action can be performed by matter save by contact, these electric bodies do not seem to touch, but of necessity something is given out from the one to the other to come into close contact therewith, and to be a cause of incitation to it.

He regards the medium which is responsible for electric attraction as different from and as more attenuated than air or water vapor. Thus he says:[2]

> All bodies are united and, as it were, cemented together by moisture, and hence a wet body on touching another body attracts it if the other body be small; but the peculiar effluvia of electrics, being the subtilest matter of solute moisture, attract corpuscles. Air, too, (the earth's universal effluvium) unites parts that are separated, and the earth, by means of the air, brings back bodies to itself: else bodies would not so eagerly seek the earth from

[1] *De Magnete*, Mottelay's translation, p. 92.

[2] *De Magnete*, pp. 87-97.

heights. The electric effluvia differ much from air, and as air is the earth's effluvium, so electric bodies have their own distinctive effluvia; and each effluvium has its own individual power of leading to union, in its own movement to its origin, to its fount, and to the body which emits the effluvium. But bodies that give out a thick or a vaporous or an aerial effluvium when rubbed have no effect; for either such effluvia are diverse from humour (unifier of all things), or, being very like the common air, they become blended with the air and one with it: wherefore they have no effect in the air, and do not produce any movements different from those of that universal and common element.

And in the air the effluvium of electrics is very rare, and so it may more thoroughly permeate the atmosphere and yet not give it impulsion by its own motion. For were this effluvium as dense as air, or the winds, or fumes of burning saltpeter, or as the thick foul effluvia emitted with much force from other bodies, or as the air from vapourized water rushing forth as from a pipe (as in the instrument described by Hero of Alexandria in his book *Spiritualia*): in such case it would repel everything, and not attract. But these thinner effluvia lay hold of the bodies with which they unite, enfold them, as it were, in their arms, and bring them into union with the electrics; and the bodies are led to the electric source, the effluvia having greater force the nearer they are to that.

The theory that an invisible emanation of some kind was given out by electrified bodies was generally held for 150 years after Gilbert's time; but there was no general agreement as to how such an emanation could bring together bodies at a distance from each other. Gilbert, as indicated above, believed that bodies are held to the earth by some kind of pressure of the air, or, perhaps, by means of the moisture of the air. He accordingly attributed similar properties to the hypothetical atmospheres caused by electric and magnetic emanations.

The Rev. John Lyon, in his *Experiments and Observations on Electricity*, published in 1780, describes the different electrical theories with which he was acquainted. He says:

The first theory I shall mention is that of the learned F. Cabeus (1585-1650), who supposed that excited amber emitted effluvia from it, which expelled the neighboring air at small distances, and they made as it were a little whirlwind by the resistance they met with from the remoter air, which was not effected by the electric streams. When this subtle effluvia could not advance any further, by reason of the resistance of the distant air, he imagined they suddenly returned to the excited amber, and carried such light bodies with them as they met with in their way.

Sir Kenelm Digby, Mr. Boyle, Hartman, and others, supposed that excited amber emitted certain unctuous effluvia, which being cooled and condensed by the circumambient air, were deprived in part of their agitations, and shrinking back to the body from whence they issued, took with them such light substances as happened to adhere to their extreme particles at the time of their retractions.

The learned Gassendus approved of the foregoing theory, but he thought proper to add, that electric rays being emitted in several directions, intersected each other, and getting into the pores of light bodies, by means of their intersections, had the faster hold, and they drew with them chaff and straws, and other substances, in their returning to the amber from whence they were emitted.[3]

It will be seen that attraction is the only phenomenon thus far explained by means of effluvia. Nicolas Cabeus, who wrote his *Philoso-*

[3]These electric rays of Gassendus almost seem to have their modern counterpart in the "tubes of force" of some of the English physicists of the present generation.

phia Magnetica in 1629, and who is referred to by Lyon as F. Cabeus, was evidently the first to observe repulsion between electrified bodies. In Chapter XXX., page 139, of the *Philosophia* he says:[4]

> I am convinced that this emanation attracts by setting the air in motion and that the air made to move in a whirl catches up the small bodies in the manner I have explained.
>
> If a face of the amber be carefully prepared (i. e. by rubbing) and is then applied to iron filings, wood shavings or similar bodies, they will be drawn strongly to the amber, but when they reach it, they will fly back and instead of falling straight downward, they will be repelled to a distance of three or four inches. It is evident then that this motion of the small bodies is on account of the movement of the air which arises (in turn) from the emanation, by which also the bodies are projected to a distance. For if it were the propulsion of the small bodies as Gilbert says, with the emanation becoming strong near the amber, they would fly back to the amber and would not be projected, just as in the case of the magnet, iron never flies back and is not repelled on coming to the magnet. But since in this case the body subject to propulsion does fly back, it is evident that the movement is caused by some external influence, undoubtedly the air.

It is plain from the above quotation that Cabeus did not recognize repulsion as a true property of electrification. Nor was it so recognized by others until the publication by Otto von Guericke of his paper, *De Virtutibus Mundanis*, in 1672.

Von Guericke recognized what he regarded as a true repulsion of his electrified sulphur globe for light bodies in its vicinity, but his explanation of the phenomenon was rather metaphysical than physical. He definitely rejected the hypothesis of an attraction by means of an atmosphere of emanation because he found that his sulphur globe could transmit its attractive power to a distance of a meter or more by means of a linen thread. The importance of this latter observation seems to have been overlooked until it was re-discovered nearly 60 years later by Stephen Gray.

Von Guericke, as the title of his paper implies, undertook to describe the various corporeal and incorporeal powers which he regarded as inherent in the nature of physical bodies. Some of these he classed as moving powers, of which repulsion was an example, and others were called conserving powers, such as gravitation. Electric attraction was classed as a conserving power and electric repulsion as a moving power. Since these powers were supposed to be inherent in the bodies themselves, they were not dependent upon a surrounding medium, and hence were of the nature of action at a distance.

In a further discusison of the various theories of electric effluvia, Lyon says:

> These theories had each their advocates in that age of Philosophy, in which they supposed that the effluvia emitted from an electric, returned to it again. After Sir Isaac Newton demonstrated the extreme subtility of the rays of light, and proved that several bodies might emit light copiously without any diminution of their weight: the doctrine of the return of effluvia was found unnecessary, and consequently was soon universally given up.

[4]Translation by Professor Jefferson Elmore.

This explanation of the abandonment of a belief in electric effluvia seems to have been influenced by Lyon's own hypothesis, which was that the light corpuscles of Newton's theory constituted the real electric fluid. Notwithstanding this explanation, the belief in an electric effluvium of some kind was retained for a long time after Newton's work on Light. In fact, Newton, himself, believed in some kind of an electric emanation. In 1675 he transmitted to the Royal Society his description of an experiment showing that a sheet of glass which has been electrified by rubbing on one side may attract light bodies to its other side, and he interpreted this as showing that the electric emanation was capable of passing through glass. He also, refers to the great tenuity of the electric emanation in two places in his *Opticks*. On page 315, he says:

> So also a globe of glass about 8 or 10 inches in diameter being put into a Frame where it may be swiftly turned around its Axis, will in turning shine where it rubs against the palm of one's Hand apply'd to it: And if at the same time a piece of white Paper or white Cloth, or the end of one's Finger be held at a distance of about a quarter of an Inch or half an Inch from that part of the Glass where it is most in motion, the electric Vapour which is excited by the friction of the Glass against the Hand, will by dashing against the white Paper, Cloth or Finger, be put into such an agitation as to emit Light, and make the white Paper, Cloth or Finger, appear lucid like a Glow-worm: and in rushing out of the Glass will sometimes push against the Finger so as to be felt.

Again, on page 327, in discussing the possibility of an all pervading ether, he says with regard to the objection of the necessary rarity of such a medium:

> Let him also tell me, how an electrick Body can by Friction emit an exhalation so rare and subtile, and yet so potent, as by the Emission to cause no sensible diminution of the weight of the electrick Body, and to be expanded through a Sphere, whose Diameter is above Two Feet, and yet to be able to carry up Leaf Copper, or Leaf Gold, at a distance of above a Foot from the electrick Body.

It seems likely that the proof that electrified bodies may retain their power of attracting other bodies for an indefinite time after being charged was one of the principal reasons for abandoning the hypothesis of a returning effluvium carrying light bodies with it. Probably the most important of these observations was due to Stephen Gray. In 1729 Stephen Gray found that many bodies, such as rosin, shellac, pitch, beeswax and sulphur, when once electrified might retain their attractive power for months, or even years, which seemed to show very clearly that electric attraction was not due to the return of the electric effluvium to its source, as Gilbert had imagined.

Gray also made another important discovery which was difficult to explain in terms of an electric emanation. He observed that a body may be given the power of electric attraction by merely bringing an electrified body near it. He performed this experiment with a ball suspended from the end of a cord more than 800 feet long, and showed

that light bodies were attracted to the ball when an electrified glass tube was brought near to the farther end of the cord. One of his favorite experiments was to suspend a boy in a horizontal position by means of loops of hair or silk and to place a table on which were some scraps of metal foil just below his head. Then when he brought his electrified tube near the boy's feet the scraps of foil rose at once to his face.

Nevertheless, fifty years after the publication of the discoveries of Stephen Gray we find physicists still explaining electric attractions and repulsions by means of an electric atmosphere surrounding the charged body. The Earl of Stanhope, who did distinguished work in the field of atmospheric electricity, published an important work in 1779[5] in which he gave the most truly scientific explanation of electrical attraction and repulsion by means of an electric atmosphere to be found in the writings of any philosopher. Stanhope does not regard the electric atmosphere as consisting of a separate emanation from the charged body, but as made up of the particles of air which have become charged with the electric fluid of Franklin, probably by contact with the charged body.

Like Stephen Gray, Stanhope tried the effect of placing a charged cork ball electroscope under the receiver of an air pump and noting the distance of separation of the cork balls as the air was exhausted. He found that the cork balls which had stood 2½ inches apart in the air fell to a separation of less than a quarter of an inch when the atmospheric pressure was about ¼ inch of mercury. He concluded from this experiment that the force of repulsion between the cork balls was proportional to the density of the air between them. Then he says:

> From these Experiments, it appears, that, when Bodies are charged with Electricity, it is the *Particles of* (*circumambient*) *Air being electrified*, that constitutes the electrical Atmosphere which exists around these Bodies.
>
> Now, since an *Electrical Atmosphere* (whether *negative* or *positive*) consists of electrified Air; it evidently follows, that the *Density* of the Electricity of that Air, must be in some *inverse Ratio of the Distance* from the charged Body, which causes that electrical Atmosphere.
>
> That electrical Atmospheres do decrease *in density*, the more the Distance from the electrified Body is increased, is demonstrable by means of a proper Electrometer, in every instance.
>
> From these simple considerations, it is easy to reduce all the different *Phenomina* of electrical *attraction* and *repulsion*, to *one* plain and convenient Principle, derived from the very nature of a *disturbed electrical Equilibrium;* namely, to the elastic tendency of the electrical Fluid, to impel every Body, charged either in *plus* or *in minus*, towards *that Part* of its electrical Atmosphere, where its *natural electrical equilibrium* would be the most easily restored.
>
> From this simple Principle, it is evident, that Bodies which are charged with *contrary Electricities*, must tend to *approach* each other, whenever the skirts of their (*oppositely* electrified) *Atmospheres* interfere.
>
> From the same simple Principle, it is also easy to understand, why Bodies, that are charged with the *same kind* of Electricity, tend to *diverge* from each other.

[5]Principles of Electricity, etc., P. Elmsley, London.

> Every Body that is electrified (whether *in plus* or *in minus*) has a constant tendency to return to its *natural State;* and this causes it to electrify, in a certain degree, *other Bodies* in contact with it, and the Air in its vicinity, in a manner similar to that explained above.

This explanation of electric attraction and repulsion was proposed long before the recognition of energy as a physical quantity; but it may easily be translated into terms of the principle that all elastic reaction to strain is directed to decreasing the potential energy of the strained system. If we substitute for Stanhope's elastic reaction of an electric atmosphere made up of charged air molecules an electric field of strain in an elastic ether, the principle here announced will enable us to explain, not only attraction and repulsion, but all the known phenomena of static electricity.

Twenty years before the publication of Stanhope's *Principles of Electricity* Aepinus had proved to his own satisfaction that charged bodies are not surrounded by an electric atmosphere of any kind. In 1759 Aepinus published his celebrated work, *Tentamen Theoriae Electricitatis et Magnetismi*, in which he stated his adherence to the general principles of Franklin's theory of a single electrical substance and attempted to develop a similar one-fluid theory of Magnetism. Aepinus expressed a firm belief that the electric fluid was wholly distinct from the ether of space, and maintained that it was confined to the limits of the electrified body and did not form an electrical atmosphere or effluvium extending into surrounding space. It is probable that it is for this reason that Aepinus is sometimes credited with being the principal founder of the theory of electrical forces acting at a distance. Thus, Whittaker, in *A History of the Theories of Aether and Electricity*, p. 48, says:

> The theory of effluvia was finally overthrown, and replaced by that of action at a distance, by the labours of one of Franklin's continental followers, Francis Ulrich Theodore Aepinus.

The latter part of this statement seems hardly justifiable in view of Aepinus' own statement of his belief. Thus on page 7 of *Tentamen Theoriae* Aepinus says:[6]

> I do not approve of the doctrine which assumes the possibility of action at a distance, for I hold as an indisputable axiom the statement that a body cannot act at a place where it is not; and if it should ever be proved that a certain attraction or repulsion does not altogether depend upon an external pressure or an internal impulse, then I think we have been reduced to such a position that we are compelled to conclude that motions of this kind are not produced by a physical force, but by spirits or other beings, as to which I cannot be induced to believe that this idea has any foundation in the world.

The arguments which led Aepinus to deny the existence of an electrical atmosphere seem to have been somewhat as follows: Since from Franklin's electrical theory all bodies upon the earth must be electrified,+electrification meaning that a body is more highly electrified

[6]Translation by Professor Jefferson Elmore.

than the earth and—electrification meaning that a body is electrified to a lower intensity than the earth, if charged bodies have an electrical atmosphere, then all bodies on the earth's surface should have an electrical atmosphere and by decreasing the capacity of an insulated body in the same electrical state as the earth it should be possible to increase the intensity of its atmosphere until it would become appreciable. Cavendish gives a similar reason for the same belief a few years later.

In 1771 Cavendish presented a paper to the Royal Society entitled *An Attempt to Explain Some of the Principal Phenomena of Electricity by means of an Elastic Fluid.* In the first paragraph of this paper Cavendish says:

> Since I first wrote the following paper, I find that this way of accounting for the phaeomena of Electricity is not new. Aepinus, in his *Tentamen Theoriae Electricitatis et Magnetismi*, has made use of nearly the same hypothesis that I have; and the conclusions he draws from it agree nearly with mine, as far as he goes.

On page 94 of his *Electrical Researches*, as edited by Maxwell, Cavendish gives his arguments against the existence of an electrical atmosphere as follows:

> That the attraction and repulsion of electricity extend to considerable distances is evident, as corks are made to repel by an excited tube held out at a great distance from them. That the electric atmospheres themselves cannot extend to any perceptible distance, I think, appears from hence, that if two electric conductors be placed ever so near together so as not to touch, the electric fluid will not pass rapidly from one to the other except by jumping in the form of sparks, whereas if their electric atmospheres extended to such a distance as to be mixed with one another, it should seem as if the electricity might flow quietly from one to the other in like manner as it does through the pores of any conducting matter.
>
> But the following seems a stronger reason for supposing that these atmospheres cannot extend to any perceptible distance from the body they surround, for if they did it should seem that two flat bodies whenever they were laid upon one another should always become electric thereby, for in that case there is no room for the electric atmosphere to extend to any sensible distance from those surfaces of the bodies which touch one another, so that the electric fluid which before surrounded those surfaces would be forced round to the opposite sides, which would therefore become overcharged with electricity, and consequently appear electrical, which is contrary to experience.

These papers of Aepinus and Cavendish seem to the present writer to furnish the starting point for that ether theory of electric attraction and repulsion which reached its extreme development in the writings of Faraday and his successors, but which seems for a time immediately following the work of Cavendish and Coulomb to have given place to the theory of action at a distance. At any rate, they mark the beginning of a rapid decline of the notion of electric atmospheres, though Stanhope's theory of the electrification of the surrounding air was published eight years after the presentation of Cavendish's paper to the Royal Society.

THE AGRICULTURAL LIMITS OF OUR POPULATION

By Professor E. M. EAST
HARVARD UNIVERSITY

RECENTLY Pearl and Reed[1] have shown that growth of population in any country is expressed by a portion of the curve of a logarithmic parabola having the formula $y = \frac{be^{ax}}{1-ce^{ax}}$, where a, b and c have postitive values. In developing this law of population increase, the authors have been guided by true biological premises, and have made the first original contribution to the problem of population since the time of Malthus. The fit obtained when the records of the United States Census are applied to this curve is truly remarkable, as indeed are the fits of census figures of other countries; and any student of population hereafter who does not give careful attention to the conclusions they have drawn, is treating his subject in a superficial manner.

The particular point in this paper to be discussed here is the major asymptote of the curve as applied to our own country. This gives the ultimate population limit of continental United States as 197,000,000, a figure so much smaller than has usually been predicted that it has aroused much comment. Doubtless Pearl and Reed realize how hazardous it is to predict. One who makes a prediction after a careful study of a situation is immediately bombarded with impromptu criticisms submitted by those who have made no such study, but who feel that in their infinite wisdom they have immediately thought of numerous variables left out of consideration by those against whom their criticism is directed. Thus it will be said that errors in the census figures will change the end result, that methods of agriculture will improve radically, that standards of living will be simplified, that new methods of utilizing energy will be found, that synthetic foods will be produced, that any one of a hundred things will occur which will make it possible for a much greater number of persons to be enlisted under our star-spangled banner than Pearl and Reed find to be probable under existing tendencies. Such criticisms are especially likely to appear on the subject of population, for a great many persons seem to take it as a direct personal insult when one suggests either the advisability of a population limit as a factor in national welfare or the possibility of a population limit as the result of natural laws. To limit

[1]Pearl, R. and Reed., L. J. On the rate of growth of the population of the United States since 1790 and its mathematical representation. Proc. Nat. Acad. Sci. 6: 275-288. 1920.

anything in the United States is blasphemy, though what the particular pleasure is in contemplating the country as an immense box of sardines, I am unable to discover. The authors would no doubt admit the possibility of certain changes in the present tendency for the population to increase. They would grant that for this reason the upper limits of our population are not to be set in 1920 with any high degree of accuracy. At the same time it could be shown, if space permitted, that criticisms of the type suggested above are not very cogent. They are the suggestions of the dilettante. The biologist realizes the improbability of new food products because of the fact that all our important foods were brought into use by prehistoric man. The geneticist is very conservative in his estimation of the prospects of a really great improvement in the domestic plants and animals. The chemist admits the possibility of synthetic foods as a laboratory stunt, but points out that as a practical scheme it is almost analogous to perpetual motion, since energy must be used up and man has never been able to approach nature in utilizing energy. The agriculturist points out the meagre changes in the art of agriculture which are the product of our civilization, and notes that those changes which have occurred are merely vehicles for exploiting a limited store of soil fertility at greater and greater speed. If there is any realm of activity wherein there is a small probability of radical future changes, it is agriculture; if there is any field wherein prediction for the future can be made from a study of the past with less likelihood of error, it is that in which agriculture is the major variant. Therefore a figure of 197,000,000 as the ultimate limit of population for the United States can not be cast aside for a *priori* reasons.

What the writer proposes to do in this paper is to show that the agricultural possibilities in this country are not so great as they are generally supposed to be, and that even if these possibilities were to be fulfilled wholly the population the country could support is not enormously greater than the figures Pearl and Reed have set. And naturally one has no good reason for saying the upper limits of food production will be reached because of population pressure. It is to be presumed that Americans will have sufficient foresight to adjust the birth rate to the death rate and to attain a stationary population without the compelling force of grim necessity. We shall not discuss the possibilities latent in new food products, in better cultivated plants and domestic animals, or in new methods of agronomy. They have been considered carefully, and it is our opinion that they are not important factors in the matter.

In an essay on population published in a previous issue of this journal,[2] the writer showed what a comparatively small amount of reserve agricultural land still exists in the United States from which to

[2]East, E. M. Population. Sci. Mon. 10: 603-624. 1919.

produce food for our increasing population—a population which is rising by leaps and bounds. Unfortunately our reference to rapid population increase has been misunderstood in various quarters. This misunderstanding was caused by our calling attention to Pritchett's calculation of our future population based on the supposed fit of our census returns to part of the curve of a third order parabola. It was obvious from its shape that this curve had no biological basis, and the absurdity of expecting 386 million people in the year 2,000 and 1,113 million in the year 2,100 was pointed out. The figures were used merely to bring out the terrific rate of increase maintained at the present time, and to emphasize the efforts necessary to provide food if this increase were to be maintained. The amount of reserve agricultural land not now in farms proved to be about 35 per cent. of the present farm area. Since in the nature of the case this uncultivated land must be of poorer quality on the average than that which has been cultivated in previous years, we are warranted in assuming that even less than 35 per cent. of reserve land remains in this country when considered on a productivity basis. These calculations were made carefully and were sufficiently accurate for the purpose for which they were used, viz., to show how rapidly our population was encroaching on our potential food supply.

Since this paper was written a detailed study of the "Arable Land in the United States" has appeared under the authorship of O. E. Baker and H. M. Strong, of the United States Department of Agriculture, as one of the papers in the 1918 Yearbook issued in 1919. These authors have made an extremely valuable investigation of the agricultural lands of the United States, and support their conclusions with adequate data. We wish to point out some conclusions as to the possible ultimate population of the country with their figures as the basis. We venture to make only two slight changes. The first change is to withhold permanently from farm use an additional 50 million acres of potential improved land to provide space for future cities, roads and railroads. The second change is a reclassification of the land, which, because of its arid nature or because of its topography, can never be used for primary food production. Baker and Reed have classed only 38 million acres out of 653 million arid acres as desert having no grazing value. But as a matter of fact about 200 million acres more are desert lands where the grazing value is negligible.

The final disposition of the lands of the United States, then, may be expected to be somewhat like this: improved land, 800 million acres; forest and woodland 360 million acres; range land and unimproved pasture 415 million acres; desert 238 million acres; cities, roads and railroads 90 million acres. One thus accounts for the 1903 million acres making up the total land area of the country.

Those who cast a distrustful eye on the 1103 million acres, 58 per cent. of the total land area of the country, which are set apart as land which must be permanently withheld from cultivation, are referred to the arguments given *in extenso* by Baker and Strong. The reasons are plainly set forth in their paper, and if the writers err they err on the side of optimistic conservatism. Their figures may have to be revised at the end of a few centuries, but it is more likely that they will be revised upward than downward.

In brief, 743 million acres of these lands are set apart because of natural irremediable conditions. They consist of arid lands having no possibility of irrigation, lands where the mean summer temperature is too low to grow crops, lands where the topography is such that cultivation is impossible, lands which are without natural soil fertility, and undrainable swamps. Nevertheless such lands, when the population pressure becomes sufficiently great, may be used to produce some food. The cheerful optimist, and we shall take on that rôle for the time being, may perhaps assume that there is the possibility of supporting one person per each 100 acres upon them—a total of 4 million people.

The 360 million acres of forest and woodland must be retained for a variety of reasons. In most cases their topography prevents their cultivation, so that they could not be used for farm lands even if no other obstacles intervened. But beyond this fact stands the opinion of meteorologists, that if this figure for a forest reserve be cut, a change in the rainfall and the temperature of the improved land would ensue such as to reduce its productivity much beyond that of any increased production resulting from the additional new lands. On the other hand, there remains the possibility of producing considerable amounts of both primary and secondary foods on these reserves without destroying their usefulness as forests and woodlands. When food becomes sufficiently scarce and the price in consequence becomes sufficiently high, these lands will be utilized. They will perhaps produce sufficient food to support one person for each 50 acres, giving an additional potential population of a little over 7 millions.

There remains, then, a potential 800 million acres of improved land for consideration. This figure is made up by adding together the 478 million acres in cultivation in 1910, 30 million acres of desert land which irrigation engineers believe may be irrigated, 60 million acres of swamps that can be drained, 82 million acres suitable for dry farming and upland pasture, and 200 million acres of tillable land which is now in woodland. The sum obtained is 850 million acres. But from this sum must be subtracted a parcel of 50 million acres to allow for the growth of cities, roads and railroads. 800 million acres of arable land are left. The question then arises; what potential population will this land support? It is a question that can be answered in a rough

way by comparing the per capita acreage of cultivated land in foreign countries as compiled by the International Institute of Agriculture at Rome.

Before the war Germany cultivated 48 per cent. of her land area, France cultivated 45 per cent, Italy cultivated 48 per cent, and Belgium 49 per cent. It will be seen that these figures are fairly comparable with the 42 per cent. proposed for the United States as the sum total of her arable possibilities. Furthermore our comparison is fair in a historical sense, since these countries were over-populated as shown by the fact that they did not live within themselves agriculturally, and since our own country is made up of peoples from similar racial stocks and therefore may be presumed to have similar tastes, customs and abilities.

On the face of the returns, these countries were tilling the following number of acres per capita; Germany 1.15 acres, France 1.5 acres, Italy .98 acres, Belgium .57 acres. These figures, however, do not show the true state of affairs. For example, the total arable land of Belgium can not be compared with that of the United States. It is much too good. It is no more right to use her wonderful bottom lands as a standard than it would be to use the Nile overflow lands of Egypt where nature robs Peter to pay Paul and produces greater crops than anywhere else in the world. It is no more proper than to expect all the soils of the United States to come up to the production figures of the Mississippi Valley. Exclude Belgium and a fair comparison can probably be made if one is careful to make the comparison fair. These countries were not self supporting. Huge quantities of food were imported annually. We have not been able to obtain the complete returns for exports and imports from which to make an accurate accounting of the number of people actually supported per acre in such countries as France and Germany where both the standard of living and the efficiency of the agriculture is high. In Germany it seems to have been pretty close to 2.2 acres per man when all corrections are made. In France it was probably somewhat higher. Personally I believe that 2.5 acres per man is the limit that we may hope to reach in the United States if we cultivate our whole 800 million acres, if we keep up a reasonable standard of living, if we follow rather closely our present food habits, if we conserve carefully our soil fertility, and above all if we farm as intensively, as scientifically and with as little waste as the best farmers of Europe who have been under the necessity of perfecting their agriculture because of population pressure during the past half-century.

If this assumption be true, our 800 million arable acres will support 320 million people, a figure to be added to the 11 millions obtained by calculating the productivity of our grazing lands and forests. The

maximum population the United States can support under any conditions conceivable to those of us who live at the present day, therefore, is 331 millions.

To be sure 331 millions of people is a right tidy little population. China is supposed to have about 300 millions, with a land area 600 million acres greater than the United States. Can we wish to be placed ultimately in an economic position less favorable than that of present day China? We should all answer, No! Is it, then, improbable that we shall use a little forethought before this time comes, and establish a birth rate adjusted to the death rate which will withold from us the economic pressure which she confronts at all times? If this be reasonable, is it not probable that Pearl and Reed's figures of 197 million, as the upper limit of the population that the United States will actually attain, are wholly just and proper?

The most optimistic of our population enthusiasts will criticize these figures no doubt. They will point at once to Japan as the shining example of efficient agriculture, an example that we ought to hold ever before us and strive to emulate. Japan, with a population of 52 millions in 1911, cultivated 18 million acres out of a total land area of 94 million acres. By an extraordinary use of fertilizers, which reached a figure of over 4.5 tons per acre over the whole cultivated area, exclusive of commercial chemicals, she was thus able to support 3 persons per acre. In reality the figures reported should not be quite so high, as Japan imported a very much larger amount of foodstuffs than she exported in the years just previous to the war. But with due allowance for imports Japan did actually produce food sufficient to support about 2.5 persons per acre of cultivated land. If the United States could do as well on her 800 million acres of arable land, our population might have a maximum limit of 2000 millions—a figure greater than the present population of the world.

Let us stop a moment and do a little more figuring before we accept this computation. The Japanese are small. Their army rations are only about one-half of ours. Their population as a whole gets along with less than half of the food per capita required by the people of the United States. Undoubtedly our own people are great wastrels because they have more to waste, and could get along with less if it were necessary; but it may be questioned whether Japan's crops would support more than 1.5 Americans per acre, even with a material lowering of the standard of living and a higher standard of efficiency for food utilization. Naturally it will be maintained by some that this difference in food consumption between the American nation and the Japanese nation is unnecessary. It will be pointed out that excess of body weight in one over the other is not over 25 per cent., and that for this reason a 25 per cent. difference in food production is all that can

reasonably be demanded. But this is not the whole truth in the matter. Food habits are very ancient. Pearl has shown that the people of the United States did not reduce their food intake during the war though there was an urgent moral necessity that this should be done. Nevertheless during this period the people not only ate just as much, they even demanded their food in whatever expensive forms appealed to their tastes. Our contention is, therefore, that while a constant economic pressure maintained over long periods may modify our food habits, it will be just as difficult for us to cut our present ration as for the Japanese to cut the one to which they have become accustomed. And it does not appear that such established folkways will be materially modified in the comparatively short length of time which present indications allow us as the interval before we reach a close approximation of our population limit—i. e., the point where our population curve turns sharply toward the horizontal.

There is still another important modification of our computation to be made. We have an extensive system of agriculture in this country. Our yields per acre are comparatively low; but we farm more land per man than any other country. The Belgian, the most intensive farmer of Northern Europe, for example, cultivated 5 acres per man before the war; the comparative figure for the United States is 26 acres. Now we have calculated that the United States contains 800 million acres of arable land that can ultimately be put under the plow, but if we suppose that this 42 per cent. of the whole land area of the country can be made to produce the crops which Japan produces on 18.7 per cent. of her area we are making a grave mistake.

Japan cultivates a comparatively small proportion of her land area by a method built up in China, because she has found that she thus gets the greatest returns. She even goes so far in her conservation and utilization of soil fertility as to strip the surface soil from less productive areas for use upon her best land. Indeed it is wholly probable, as may be seen by a study of the relief maps of the two countries, that Japan has almost as high a percentage of arable land as the United States. But she has found that it does not pay to try to cultivate it all. We have considerable reason for supposing that Japan would not obtain a significant increase in her total production of foods if she cultivated 42 per cent. of her area instead of 18.7. If, therefore, her productiveness were measured in relation to the first percentage (42), she really would need 1.5 acres per man to support her population in terms of American food habits. At this rate, the United States could support only 530 millions on her arable land. Presumably this figure may be taken as the ultimate limit humanly possible for the country. That we shall ever reach this figure seems to the writer wholly absurd.

THE BEARING OF THE RESULTS OF MENTAL TESTS ON THE MENTAL DEVELOPMENT OF THE CHILD

By Professor FRANK N. FREEMAN

UNIVERSITY OF CHICAGO

IT is surprising to note how little the results of mental tests have been used as a basis for a critique of our views of the mental development of the child. These views have become traditional and are based upon data which were gathered before the present day era of mental testing had opened. The scientific facts upon which our current conceptions are based are exceedingly slender in comparison with the rich material which now awaits our formulation. It is probably no exaggeration to say that there is now available for interpretation ten times as much material bearing upon the age progress of the child in intellectual functions as was available ten years ago. I have attempted in this paper to make a survey of the most significant of this material and to examine critically our conceptions of intellectual growth in the light of it. In the examination of the data we should consider such questions as the following:

1. Age progress in particular intellectual functions.
2. Age progress in more general or composite intellectual functions.
3. The correspondence between this age progress and physical growth and development.
4. The relationship between the progress of the average or median child and the progress of those who are above or below the median.
5. The relation between the facts already mentioned and current methods of expressing the relationship between the individual of inferior or superior ability and the individual of median ability. This question deals particularly with the now commonly used I. Q. (Intelligence Quotient).
6. The nature of the differences in the intellectual capacity of children at different ages. This topic raises the question whether the differences are chiefly in amount of ability or whether there are also differences in kind. In other words, the problem is whether the child simply increases, through development, the powers which he already possesses, or whether he acquires new powers as he grows older. This topic is not included in the present discussion.
7. Finally, we may consider some of the practical bearings of the facts upon such problems as the grouping of the children in school.

Age Progress in Particular Intellectual Functions

We may introduce the topic of age development by examining some of the chief data which were gathered by earlier students of this problem. About 1900 Smedley made tests of memory on a large number of school children. He presented the results of this test in the form of a curve which represents the achievement of the child at each age

from 7½ to 19½. The type of memory which was tested was a very simple one, namely memory span for digits. It consisted in requiring the child to reproduce a series of numbers which were spoken to him or presented to him visually. The curves for visual and auditory memory are shown in Fig. 1. From these curves the conclusion has been drawn that auditory memory ceases to improve between the ages of 13 and 14 and the visual memory between the ages of 14 and 15. In other words, memory develops rapidly until early adolescence and then practically ceases to improve. It is rather astonishing that so far-reaching a conclusion should have been drawn from an experiment with only one type of memory and that a very simple one. We shall see from the examination of the other progress curves that the age at which improvement ceases depends in a large measure upon the difficulty and complexity of the test which is used. It is quite unjustified to conclude that memory for narrative, or for expository prose, or for poetry follows the same course of development as memory for digits.

The difference in the age at which progress slows down or ceases is shown in the three examples from a still earlier investigator, Gilbert, whose report was published in 1895. A careful examination of Gilbert's results indicates that the age at which one function matures may be very different from the age at which another reaches its climax. Chart No. 2 shows the progress in discriminating differences in color. We see that this ability ceases to develop rapidly at 10 years. The break in development comes in the middle of the period of later childhood, between second dentition and adolescence. In the third chart is shown progress in the discrimination between weights, which Gilbert calls muscle sense. The development in this capacity apparently ceases at the age of 13, in early adolescence. Development in rate of movement, as tested by rapidity of tapping, (Chart 4), shows a break at the age of 13, but unlike the muscle sense continues its development after this break up to the age of 17. In another investigation of progress in tapping there is no such clear break at 13 as was found by Gilbert. Chart 5 from Bickersteth shows fairly continuous progress up to the age of 14½. We have thus already found a considerable variety in the time of maturing of various functions.

The following charts will illustrate further this variety in the form of progress of relatively simple functions. Chart 6 represents progress in a test which consisted in marking with a pencil a succession of dots. The speed of the dots was progressively faster so that the test passed from easier to more difficult stages. The progress in this ability shows no radical retardation from the age of 5½ to 15½, though there are minor retardations at 10½ and 13½. In general, however, the curve of the line of advancement is straight up to the age of 15½.

The next chart shows progress curves in three examples of another

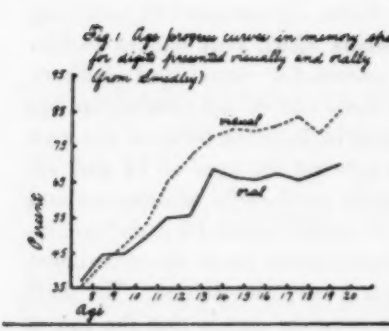


Fig. 1. Age progress curves in memory span for digits presented visually and orally (from Smedley)

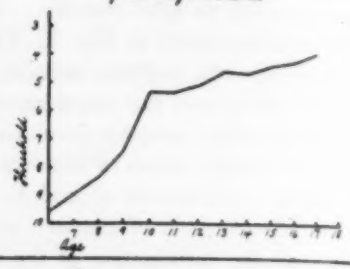


Fig. 2. Age progress curves in discrimination of color (from Gilbert)

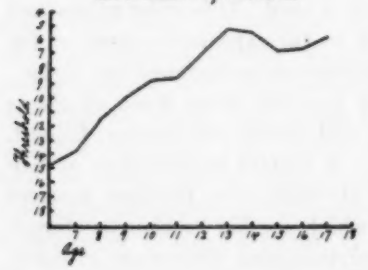


Fig. 3. Age progress curves in weight discrimination (from Gilbert)

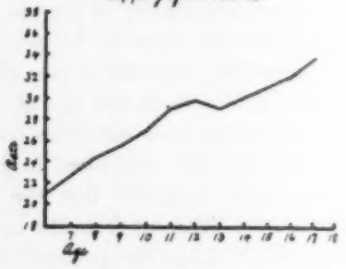


Fig. 4. Age progress curves in rate of tapping (from Gilbert)

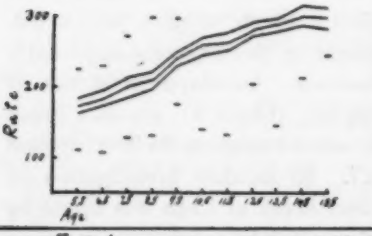


Fig. 5. Age progress curves of girls in rate of tapping (Bickersath)

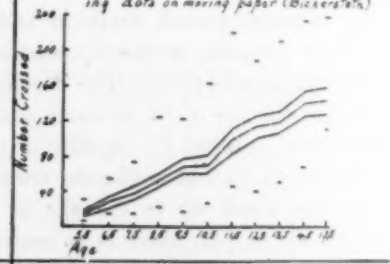


Fig. 6. Age progress curves of girls in marking dots on moving paper (Bickersath)

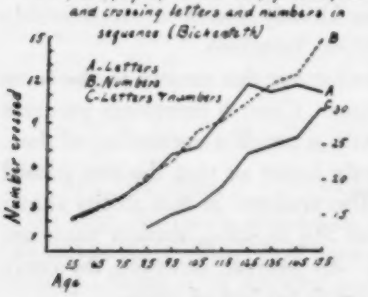


Fig. 7. Age progress curves of girls in finding and crossing letters and numbers in sequence (Bickersath)

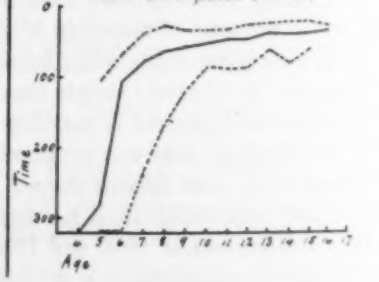


Fig. 8. Age progress curve in a simple construction puzzle (Pintner)

test. The test is given by presenting to the child a card upon which are arranged letters of the alphabet and numbers in irregular order. The problem is to cross out the letters of the alphabet or numbers in order. In the third form letters and numbers are mixed. We see that in two of the tests, namely crossing numbers and crossing numbers and letters combined, there is no let up in progress up to the age of 15½. There is a slight break at 13½ in the combination test but none in the number test. In the alphabet test, however, progress ceases at the age of 12½. There thus appear radically different forms of progress in the tests which superficially seem to be practically identical. It is impossible to predict where a break in progress will come on the basis of a knowledge of the general character of the test. It is equally incorrect to say that the break of progress in different tests will come at any common age.

A similiar variety in the ages at which ability culminates is seen in three examples from the performance tests given by Pintner and Patterson. The first of these is the so-called triangle test. It consists in fitting triangular pieces into an opening. It is an example of the form board test. The culmination in this ability comes at the age of 6, with very slight progress after this age. There is enormous progress between the ages of 5 and 6 (chart 8). Another form board test used by Pintner, on the other hand, shows this rapid progress at a different age. It is the so-called picture profile test in which the task is to place a number of blocks so as to form the outline of a face. The rapid progress in this test comes between the ages of 9 and 11, and the culmination is practically reached at the age of 11 (chart 9). Chart 10 shows somewhat more gradual advance with age, in which the most rapid progress comes between 5 and 9, slower progress between 9 and 12, and practically no progress after this age. This is the so-called picture completion test. A series of parts of a picture pasted on a board are cut out of a picture and mixed with a number of blocks on which other pictures are pasted. The task is to select the proper block from the collection and insert it in the proper opening in the large picture. The range of chances of correct moves is large and the scoring system is worked out in considerable detail. Progress is therefore represented in a more refined fashion than in some of the preceeding tests.

The examples thus far have been drawn from general mental tests, which measure somewhat abstract abilities. The same differences in age of maturing of different functions can be illustrated, however, from tests in school subjects. On chart 11 are shown three curves of advancement in reading from Gray's investigation. The continuous line shows advance in the rate of oral reading, the broken line in the rate of silent reading and the dotted line in quality of silent reading. It will be

Fig. 9. Age progress curve in a simple construction puzzle (Pintner)

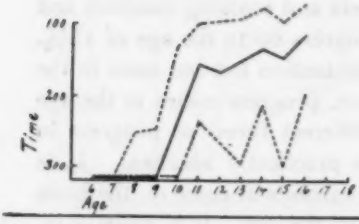


Fig. 10. Age progress curve in a picture completion puzzle (Pintner)

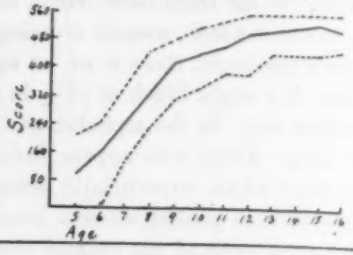


Fig. 11. Grade progress curves in reading (Gray)

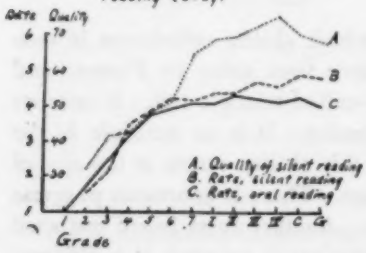


Fig. 12. Average age in the school grades

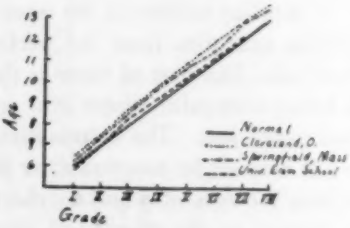


Fig. 13a. Percentage of children testing below age who reach or exceed those of same mental age who test at age in nine single tests (Evans and Castle)

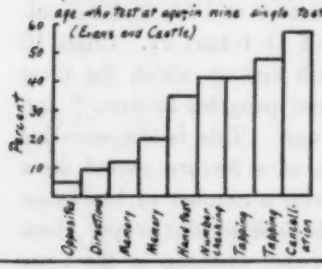


Fig. 13b. Diagram illustrating the relative effect of age on the scores of various tests shown in Fig. 13a, and in the Yerkes Point Scale, these used as basis for mental age

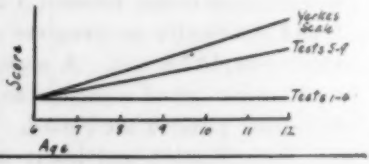


Fig. 14. Grade progress curves in simple multiplication and division (Judd)

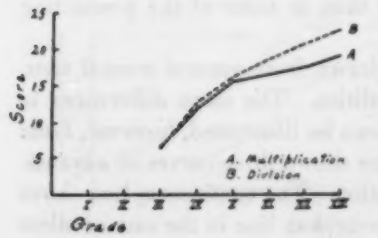
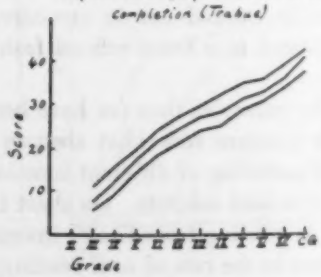


Fig. 15. Grade progress curves in sentence completion (Trabue)



seen that the progress in rate of silent and oral reading is relatively very similiar, although the rate of silent reading is above that of oral reading from the fourth grade on. The curve for quality of silent reading, however, takes a radically different course. There is marked and continuous progress up to and including the Senior year of the High School. It is probable that this progress would continue through the further two groups which were tested, namely college students and graduate students, if their attitude toward the test had been as natural as that of the younger pupils.

The question of technique in the interpretation of these tests arises from the fact that, unlike the preceeding tests, the results are grouped by school grades rather than by ages. If the pupils of successive grades were all of the same age, and if each grade represented an advancement of one year in age over the preceeding one, the curves would be based upon the same groupings. Neither of these conditions, however, obtains. The relation between age and grade may be illustrated by a chart showing the average age of pupils in successive school grades. On chart 12 is shown by the continuous line, the normal age for each school grade, assuming the pupils enter at six years and advance one grade each year. The next line above represents the average age for the successive school grades in the University Elementary School. It appears that in all grades except the first two the average age is somewhat above the normal. The other broken lines represent the same facts for Springfield, Mass., and for Cleveland, O. The average age in the public schools is considerably above that both of the normal and the University Elementary School for each grade.

Assuming that the results from school grades would be the same as results from age groups if the average age corresponded to the normal expectation, we may ask what effect this deviation of the actual from the expected may have upon age progress curves. In order to answer this question it is necessary to know whether the average score in a test would be raised or lowered by the fact that the average age of the grade is above normal. The question may seem at first sight ridiculous, but it ceases to be so when we consider that the pupils who are above the normal age in any particular grade are retarded because of backwardness in mental growth. Investigations have repeatedly shown that the younger pupils in the same grade may do better in certain tests than the older pupils in the same grade. In such a test, therefore, the excess in the average age of the pupils might be expected to lower the curve at the point at which it occurred. On the other hand, it may be true that in some tests the older pupils would do better than the younger pupils of the same grade. We might for convenience call this type of test a maturity test, and the type in which the younger pupils excel a brightness test.

Fig. 16. Grade progress curves for completion of sentences of varying difficulty (Trabue)

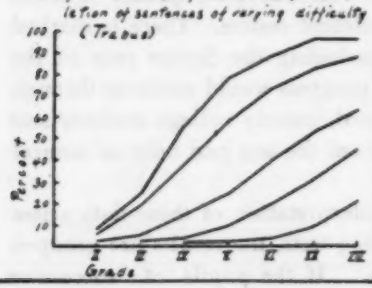


Fig. 17. Age progress curve in the Yerkes Point Scale

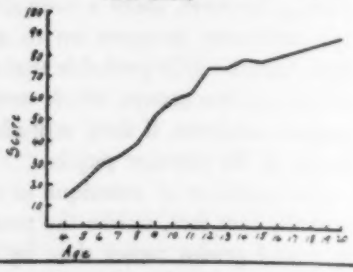


Fig. 18. Age progress curve in the Pressey Group Test

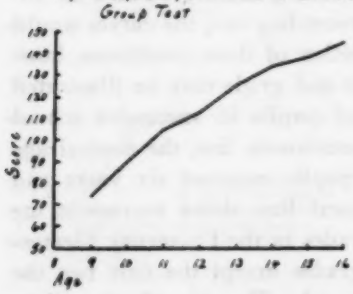


Fig. 19. Grade progress curves in Forms A and B of the Chicago Intelligence Test

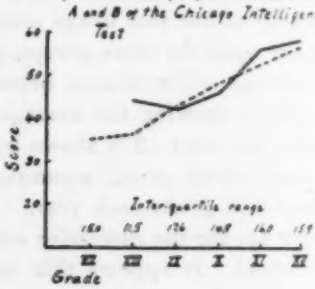


Fig. 20. Age progress curves in Haggerty's Tests Delta 1 (A) and Delta 2 (B).

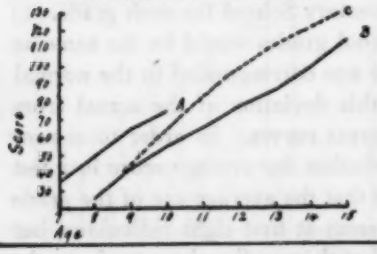


Fig. 21a. Hypothetical age progress curves in Intelligence (Woodrow)

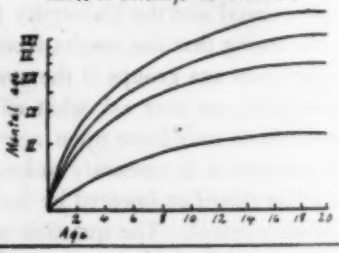


Fig. 21b. Hypothetical straight-line age progress curves

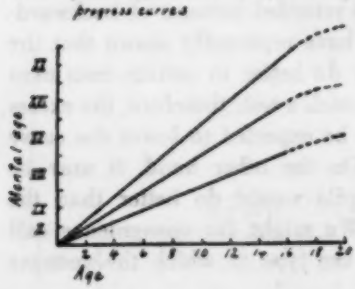
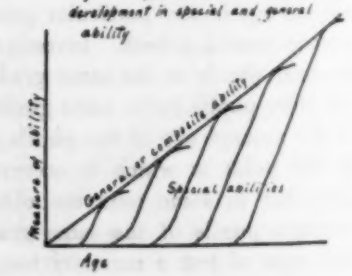


Fig. 22. Hypothetical relation between development in special and general ability



That there are such differences between tests is made clear by Chart 13a. In the upper part of the chart are represented the scores in a variety of tests given to a group of children. These children varied in chronological age, but were similiar in ability as measured by the Yerkes point scale. This group, homogeneous so far as their ability in this scale was concerned, were given nine tests. In order to compare the factors of brightness and of age in these nine tests the entire group of children was divided into two groups. The first consisted of all those whose mental age did not correspond to their chronological age. For the most part their ages were above the normal. In the other group the mental and the chronological ages correspond, that is, their mental advancement was what might be expected from their age. The relative standing of these two groups was thus compared in each of the nine tests. Each horizontal column represents one of the tests, the first column an opposite test, the second a directions test, the third a memory test, etc. The length of the column represents the percentage of the older children of the group who exceeded the median of the normal children. If the column reaches fifty per cent., as it does in the last two tests, it indicates that the two groups are equal. If the column is short it indicates that the older children are inferior to the younger ones. In the last five tests, which consisted in simple sensory and motor processes, the older children were nearly equal or fully equal to the younger ones, while in the first four they were markedly inferior. We may express these facts by saying that in some tests, physical maturity, as distinguished from brightness, is of little avail, whereas in others improvement accompanies to a much greater extent mere chronological age.

We may express the differences between these types of abilities by the figure chart 13b. The lines indicate the relative degree of advancement we may expect in a test from mere physical maturity. Thus we see that in the Yerkes scale and in tests 5 to 9 the factors of maturity and of brightness have about the same relative influence, while in tests 1 to 4 the factor of brightness outweighs that of maturity in comparison to both the Yerkes scale and tests 5 to 9.

To come back now to our interpretation of the grade progress curve, we may say that if the test in question depends largely upon physical maturity the curves which represent it will be higher in intermediate grades, and in some cases in the grammar grades, than would be the same age progress curve. If the test is one of brightness however, it is probable that the curves would either not be raised or would be slightly lowered by the excess age of children in these grades.

Since the above was originally written both an age and a grade progress curve in the same test have become available for the Haggerty test, Delta 2. These curves are shown in Fig. 20, B and C. The

age progress curve is practically a straight line while the grade progress is more rapid up to Grade VI and then decreases. The form of the grade curve suggests that success in this test depends largely on maturity. From the third grade to the fifth the number of over age, dull, pupils increases, while the number of under age, bright pupils decreases. After the sixth grade the number of over age pupils decreases rapidly and the number of under age pupils nearly holds its own. There is one serious difficulty in the interpretation of these data, however. The superiority of the grade progress curve is much greater than can be accounted for by the preponderance of over age pupils in the grades and the assumption that the score depends chiefly on age. For example, the average age of eighth grade pupils in two cities, Cleveland and Springfield, Mass., is 13.66 years and 13.53 years respectively. The score for year 13.6 according to the age norms would be about 95, but the score for grade VIII is 120. Since the results come so far from fulfilling the legitimate expectations in this respect, then, we may well be hesitant in drawing the natural conclusion which is suggested above from the form of the curve, particularly since the younger children of a school grade have been shown repeatedly to make a higher score in tests of this sort than do older pupils. The question of the relation between age and grade progress curves must be left open to further investigation.

We may then use these grade progress curves to represent roughly progress with age but must bear in mind that they may be somewhat distorted. Another illustration from school subjects is given in chart 14 which represents grade progress in simple multiplication and division as measured in the Cleveland Survey. While there is continuous progress in division to the eighth grade, there is a marked break in progress in multiplication at the fifth grade. Thus in two of the operations in the same school subject we find the progress curves representing different periods of maturing.

Age Progress in General or Composite Functions

Progress curves which have been shown up to this time represent development in fairly specific mental functions. We may compare with these a number of curves which represent somewhat more complex functions or composite functions. The first one, shown on chart 15, is not greatly different from those which we have already been shown. It represents progress in ability to complete mutilated sentences as taken from the study of Trabue. The sentences are so arranged as to advance from very easy to difficult. This makes possible a wide range of scores and gives an opportunity for pupils of little ability and also for pupils of much greater ability to be faithfully represented in the score. The progress curve on this test is accordingly very different from that which was obtained in most of the preceeding

examples. It represents an almost uniform rate of progress from pupils in the second grade to college graduates. This means that the development in the ability which is required in this test is practically uniform. The facts here represented suggest very strongly the view that the form of progress in which there is rapid gain within a small range of ages, followed by little gain, is due to the fact that the test is of such a character as to measure only a given degree of difficulty, or given level of ability, in the function which is measured. It suggests that if a test were so designed as to give opportunity for all ranges of performance in a function, the curve would show more continuous and extended advance.

That this hypothesis is a reasonable one is indicated by the next chart, No. 16, in which curves for several individual sentences of the Trabue test are given separately. The upper curve obviously represents an easy sentence, since the ability to pass it develops early. The lower curves represent successively more difficult sentences. We have here then a succession of progress curves in the same function, which take radically different courses, and represent development at widely different ages. It is obvious that a marked development at a particular age distinguishes it from the others, not in a marked advance in the function as a whole, but rather in what we may call a particular cross section of it, or particular degree of capacity in it. Progress in a function as a whole is uniform and extended over many years.

Similiar uniform and extended progress is represented in the scores of four point scales. A point scale is usually similiar in organization to the Trabue scale in that it includes materials of widespread range in difficulty. An individual's score is made up of the sum of the points which he is able to make in all of the tests which he can pass. These scales, in addition, go one step further in including tests of a variety of sorts of functions. In the first record of progress in a point scale, namely the Yerkes scale, shown in Chart 17, the progress is continuous and uniform up to the age of 12. From that point forward to the age of 20, there is further uniform progress, but at a much slower rate than that below the age of 12. If we reason from this alone, we should conclude that there is a break in mental development at the age of 12. It is quite possible, however, that break in progress is due to the fact that the scale does not furnish as great an opportunity to individuals of the upper degrees of ability as to those in lower ranges. That this supposition is correct is indicated by the fact that progress in the Pressey test, chart 18, and the Chicago Intelligence Test, chart 19, follows a uniform course beyond the age of 12. In the Pressey test this uniform progress is carried as far as age 16, and in the Chicago test to the senior year of the high school. Some allowance should probably be made in the case of the Chicago

test for the selection of the brighter pupils in the later years of the high school. This factor, however, is probably not responsible for the great difference found between this test and the Yerkes test.

Additional evidence that progress with age as measured by composite tests follows approximately a straight line within the ages during which growth is continuing is to be found in the norms from the Haggerty point scale, shown in chart 20. The irregularities in the curves are readily explained. The falling off in progress in A at 10 years is doubtless due to the fact that this test is too easy for this grade. Likewise the low score in B at age 8 is due to the difficulty of the test for 8 year old children. The acceleration in B at the age of 15 years is probably due to a selection of the brighter children at this age.

Hypothetical Growth Curves

We may now make an attempt to generalize upon the facts concerning intellectual growth which are represented in the preceeding charts. We may first consider the question as to the general form of the development curve. The fundamental question which arises here is whether development preceeds in general at a uniform rate or whether it is more rapid at one period than at another. Disregarding the question whether there are minor accelerations or retardations in rate, the first question to be considered is whether growth in general is more rapid in the early period of childhood or later on, or whether the progress follows some other course. The widespread view on this matter is represented in the upper curves of chart 21a. This view has been given some support from the analysis of the results of the Binet scale. The particular curves here shown are taken from Woodrow. They represent intellectual growth as being very rapid in the earliest years and becoming progressively slower until it practically ceases at the age of 16. A different conception is represented in chart 21b. According to this conception, progress is comparatively uniform in rate from early childhood to maturity. The limit of progress, furthermore, comes at least somewhat later than the age of 10. Again the same point must be made as was mentioned in the comment on the Yerkes scale. When progress appears to cease at a given age, it is not safe to conclude that this cessation is actual unless we are sure that the tests give an opportunity to superior degrees of ability. There is reason to believe that the Binet tests do not do so, and that therefore the conclusion that progress ceases at 16 is not justified. At what age progress does show marked slowing down we cannot at present say. In all probability it continues with considerable rapidity to the age of 20.

The further discussion of the validity of these two conceptions of

age progress is so bound up with the question of individual differences and of overlapping ability of succeeding ages that it can be best taken up after presentation of data upon this matter. We may add, however, a chart which represents a view of mental development which is in harmony with the facts already presented. The figure representing this view is shown on chart 22. On this chart is indicated the relationship between general intellectual progress or composite progress, represented by the straight line, and progress in a series of particular capacities or in narrowly defined measures of general capacities or functions. Such a conception reconciles the superficially contradictory facts shown in the preceeding charts. In some of these, progress seemed to be confined to particular ages while in others progress is spread over a wide range. The view here suggested is that progress in general or composite functions is widely extended, but that this general progress is contributed to by increments of ability in narrow functions or in different applications of a function coming at definite stages of maturity.

A word may be said in explanation of the apparent difference between this picture of the progress curves in particular abilities and the curves taken from separate sentences of the Trabue test. In the former chart the individual curves for more difficult sentences are progressively lower on the chart. In the present chart the curves representing the scores in more difficult tests mount successively higher. The difference is simply one in the mode of representation. In the earlier chart the height of the curves represented the absolute score in the different sentences and the more difficult sentences are therefore lower on the chart. On the present chart the height of the curve represents the degrees of ability indicated by the score, and it is therefore greater in the case of tests of greater difficulty.

Relation of Age Progress to Individual Differences

We have thus far been dealing with average or median progress from age to age or grade to grade. It is well known, of course, that the absolute ability at succeeding ages represented by such median or average curves stands for comparatively few individuals. The range in ability above and below such medians or averages, or the knowledge of the fact that there is such wide range is to so great an extent common property that it is not necessary to dwell upon it. A few illustrations may be given of the extent of this individual difference and we may then pass to certain more particular and less generally known aspects of the matter.

On chart 23 are shown distribution curves in ability in the Trabue scale for selected school grades. The breadth of the distribution is illustrated by the fact that there are pupils in the second grade who get as high a score as pupils in the eighth grade. There is a con-

siderable number of fifth grade pupils who do as well as college graduates. Further illustration may be found on some of the charts from the study of Bickersteth. See, for example, the results of the tapping test, shown on chart 5. The extreme cases are represented by the short lines at the upper and lower parts of the chart. Thus we see that there was a thirteeen year old girl whose tapping rate was below median for the fifth year, and that an eight year old girl made a score equal to a fifteen year old norm. Similar wide ranges appear in the dotting test, shown in chart 6. A further illustration may be taken from results of the picture completion test, chart 10. The dotted lines on this chart include the middle half of the various age groups. We see, for example, that an individual at the upper limit of the middle half at age eight made a score equal to the median at age 10, and equal to the individual at the lower limit of the middle half at the age of 13, five years later. Such facts as this mean, of course, that there is as

Fig. 23. Distribution of scores of five groups in the Sentence Completion Test (Trabue)

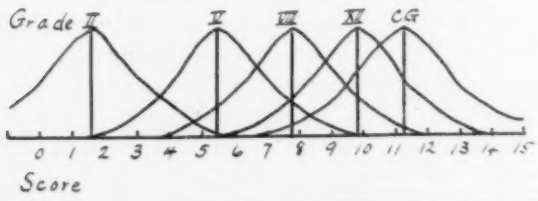
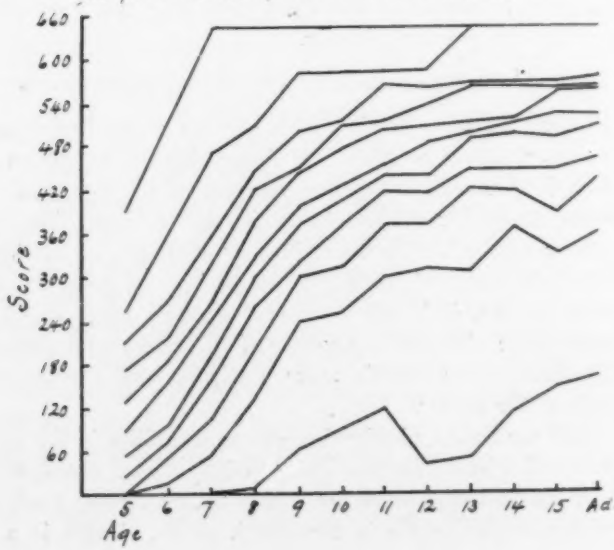


Fig. 24. Age progress curves of ten percentile groups in picture completion Test (Pintner)



much overlapping in ability in tests of a general character as we have become familiar with in the case of tests of school subjects.

The question which particularly concerns us here is the bearing of these individual differences upon the form of age progress or, in other words, the relationship between progress from age to age of individuals of different degrees of ability. Does the individual at the lower part of the scale advance by the same stages as the more able individual, or is the form of his progress different? Illustrations which have already been shown suggest that the form of progress in the case of individuals of differing ability is similiar but that their progress is at different levels. This relation is more clearly shown on chart 24. We have here shown ten progress curves, each one representing a given level of ability. These curves are obtained by dividing the individuals of each age group into ten equal sub-groups and finding the scores of each of these smaller groups. It is remarkable that these curves are practically uniform in showing a break in progress at the age of 9, and another somewhat less pronounced break at the age of 11. The test from which this table was made is the picture completion test. It thus appears that whether an individual is of low or high ability he comes to the culmination in his development at practically the same age. This means that insofar as there is a break in the general curve of progress we may expect to find this break at the same point in the lives of different individuals. This is a remarkable and somewhat surprising fact of individual differences. Before adopting it with entire confidence, we should have further evidence of the same sort as that which is here represented, and also a record of the progress of individuals through a succession of years such as will be suggested later, but our present data seem to warrant the conclusion stated above.

The second problem regarding individual differences in their relation to age progress may perhaps be best discussed from the point of view of one of the well known devices in mental testing. This device is a method of expressing the relation between the ability of individual and the ability of the group. In the earlier period of the use of age scales this relationship was expressed in the form of the difference between mental age and chronological age. If the child was able to pass tests equivalent to the ability of the 10 year old child and if he was actually 12 years of age his intelligence was expressed in terms of two years' retardation. It appeared after a time in the experience of those who used the Binet scale that this method did not represent equally the retardation or advancement of children at different ages. Two years' retardation at the age of 6, for example, was found to be more serious than two years' retardation at the age of 12. In fact, it was found empirically that one year's retardation at 6 was about equivalent to two years at 12. The degree of retardation or advancement then came to be expressed in the form of a ratio of mental age to chronological age

rather than in the form of the difference between mental and chronological ages.

It is obvious that this practice, and the theoretical basis for it, have bearing upon our conception of intellectual progress. The explanation which has been commonly accepted, and which is perhaps the most natural, is that the rate of progress is continually diminishing. This view is represented on Woodrow's chart already referred to (Number 21a). It may readily be seen how this form of progress would give the basis for the Intelligence Quotient. Compare, for example, the position of the normal individual represented in the middle curve and the moron represented in the next lower curve in relation to one another at the ages of 6 and 12. The six year old moron is practically at the same level of ability as the four year old normal child. The twelve year old moron, on the other hand, is at practically the same level as the eight year old normal. Thus the ratio between the mental ages of the individuals remains constant, which is what we should expect.

There is another condition, however, which would give the same constant intelligence quotient, and which would permit the hypothesis that the rate of progress is uniform rather than decreasing. That condition is illustrated in chart 21b. This assumes that the progress lines of various individuals of differing ability are straight and that they diverge in the upper ages. The consequence of this would be that the range of distribution of the individuals in successive age groups would become greater. Take again, for illustration, the comparison between normal and low grade individuals at ages of 6 and 12. The low grade individual at age 6 is equivalent in ability to the normal four year old, and the low grade individual at age 12 is equivalent to the normal eight year old. The ratio remains constant.

We thus see that the problem of the intelligence quotient involves two conditions rather than one. It depends upon both the form of progress and the spread of distribution at successive ages.

In support of the view that the rate of progress is a diminishing one, the fact that there is more overlapping in the scores of adjacent ages in the upper age levels than in the lower ones is sometimes cited. Thus, if we compare the percentage of the 5 and 6 year old pupils who pass the six year old tests in the Stanford Revision of the Binet scale we find that the average difference is 23 per cent. If, again, we compare the standing of the 10 and 12 year old children in the 12 year old tests, the difference is nearly the same, namely 26 per cent. This means that in the tests that are used in the Binet scale there is more overlapping between successive age groups in later than in earlier ages. It is clear that this increase in overlapping in the latter ages is the justification for the use of the Intelligence Quotient with the Binet Scale.

The cause of this difference in the overlapping at different ages has been assumed, as has already been said, to be due to diminution in the rate of mental development. It might equally be due to the increase in the range of distribution of the individuals of the higher ages. Our next problem then is to determine what the actual cause is, and whether this cause pertains to all tests, so as to determine whether the method of expressing intelligence by the Intelligence Quotient is universally appropriate.

With reference to the question whether age progress follows a straight line or a negatively accelerated curve, numerous progress curves which we have before us give some evidence. The general fact is that narrowly specialized functions give a curve whose rise is slower in the later ages than at some earlier age or succession of ages. On the other hand, a test of a more composite nature, which offers the opportunity of a wide range of scores, gives something nearly approaching a straight line progress. We cannot determine what the type of progress is in the Binet scale since it is not scored in absolute units, but in terms of mental age. The whole scale is standardized in age terms and therefore cannot be used directly to indicate the type of age progress. This is the reason why resort has been had to the indirect method already mentioned. The burden of evidence seems to be that a composite test like that of the Binet scale ordinarily gives straight line progress provided a sufficiently wide range of scores were possible.

We may then examine the other possible explanation of the fact that the Intelligence Quotient is valid when applied to the Binet Scale, assuming for the moment that it should give a straight line progress if scored in absolute terms. The other possible hypothesis is that increased overlapping in the upper ages is due to an increase in the range of distribution of the individuals. We may examine a number of cases in which the range of distribution has been calculated. Reference may be made to charts No. 5, 6, 8, 9, 10, 15, 19, 24. In this fairly comprehensive group of tests there does not appear to be any general tendency to increase in the range of distribution of scores in the upper ages. It seems legitimate, therefore, to eliminate this as a cause of increased overlapping in general, and in the Binet scale in particular.

The conclusion to which we are forced, if these inferences are correct, is that the Binet scale is an exception to the majority of composite tests, in that it actually does give decreasing of rate advancement in the later years. This inference is strengthened by the fact that the Yerkes scale, which applies a method of absolute scoring to some of the Binet materials, gives a decreasing rate of advance beyond the age of 12. That such a form of development, however, is to be regarded as characteristic of intellectual life in general is not to be concluded. It is due, in this case, as evidence seems to warrant, to limitations of the Binet scale in the upper ranges of difficulty.

This conclusion has bearing upon the tendency which is being manifested to apply the same method of reckoning intelligence by means of the Intelligence Quotient to scales in general, since there seems good warrant for the belief that neither a diminishing rate of advancement nor increased spread of distribution is characteristic of the scales which give sufficient range of difficulty at the upper levels, up to the period of middle adolescence at least. It is very doubtful whether the Intelligence Quotient is to be generally applied. It seems likely that it might turn out that the earlier difference between chronological and mental age may be more generally applicable.

A few supplementary topics may be discussed very briefly.

Correspondence Between Physical and Mental Development

A survey of the curves of growth in special and general functions seem to give little ground for the theory that widespread and general crises or stages in mental growth correspond to particular stages or transitions in physical development. The two prominent turning points in physical growth are second dentition, occuring at about eight years, and adolescence, beginning, roughly, at about twelve years. Particular functions show rapid growth at certain ages, and these stages in growth come at very similar ages in different children; but cases can be found of rapid development occuring at practically any age. It is simply necessary to choose an appropriate mental process, or a test of appropriate difficulty, in order to find rapid development at any point. Composite or general curves show very little tendency to break at any particular age. If there is any such tendency it is comparatively slight, and is more likely to come in the neighborhood of the year twelve than at any other time. This may be interpreted, probably, as due to some general disturbance resulting from physiological and instinctive changes rather than to any fundamental and deep-seated effect of growth changes upon intellectual capacity.

These conclusions are, of course, limited to intellectual capacity, which is the function measured by these tests. No implication at all is intended with reference to emotional attitudes, instincts or interests. This may very likely be much more closely related to stages in physical growth than are intellectual capacities.

Practical Application of the Above Conclusions

It is clear, in the first place, that the child passes through fairly clearly marked stages when his progress is measured by his achievement in narrowly defined capacities, or by tasks of definite degrees of difficulty which are examples of general functions. Thus the child's ability in color discrimination or pitch discrimination, in oral reading or adding or subtracting, and perhaps as well in certain aspects of the content subjects—history, geography, science not yet defined—culminates

at specific ages. Training should obviously be adapted to these periods of culmination.

Just how this adaptation should be worked out is not quite clear. Take pitch discrimination as an example. Should training be emphasized during the period when the function is developing rapidly or should it await the time when the development of the function culminates? It is quite possible that this question must be answered differently for functions which develop relatively spontaneously, such as sensory discrimination, and those in which specific school training is a much larger factor, such as facility in the number operations. We do not know without more scientific experimentation on this point, how far down the culmination in particular school abilities may be pushed, nor do we know what the relative length of the period of training would be at different ages. In the case of the school subjects the facts of age progress are complicated by the training factor.

The results of mental tests throw some light on the urgent problem of grouping pupils in classes. If pupils are grouped according to their absolute ability children of different ages and of different stages in the development of their mental functions will be put together. This is well shown in chart 21. In presenting this chart Pintner suggests that such a grouping may be desirable. It is very questionable, however, whether it is so. Such a grouping brings together pupils who are unlike, not only in their general social attitudes and instinctive development, but also children who are at different stages in the development of particular intellectual functions. The traditional method of grouping which brings together children of about the same age, makes it necessary, on the other hand, to handle in the same class pupils of vastly different absolute ability. The difficulties of this procedure are evident to every teacher. The only satisfactory solution is to group together pupils who are alike both in stage of advancement and in absolute ability. When the numbers are too small to allow the number of groups which this arrangement involves it is necessary to meet the situation by individualizing instruction as much as possible.

Do the facts indicate that there are clearly marked crises in general intellectual development, or that there are ages at which a culmination in a sufficiently large number of particular functions occurs simultaneously, to warrant, on the basis of intellectual development alone, an administrative division of the school into units? The writer does not believe that they do. It is quite possible that such a division is justified on other grounds. When the pupils arrive at a given stage of maturity, they may be prepared for a different form of organization, such as more extensive departmentalization, or more specialization, simply because they have reached such a level of maturity as fits them for an objective task of a given difficulty or complexity. But this would

not imply either having arrived at such a level suddenly or ceasing to progress beyond it. Furthermore the necessity for a new type of organization, such as is represented in the Junior High School, may arise from the acquisition of new interests and social attitudes, quite apart from intellectual ability. The introduction of a new form of organization, then, is dictated, in all probability, not so much by clearly marked stages in general intellectual development, as by the broadening out and specialization which follows the pupil's mastery of the common fundamentals of his education and by the necessity of a different type of management which results from the pupil's new social attitude.

THE PROGRESS OF SCIENCE

THE WASHINGTON MEETING OF THE NATIONAL ACADEMY OF SCIENCES

The annual meeting of the National Academy of Sciences was held at the National Museum in Washington on April 25, 26 and 27, with an attendance of about seventy of the some two hundred members and a scientific program of forty papers. The programs always maintain high scientific standards, but the different papers vary in interest, being sometimes discussions of new advances of concern to all and sometimes technical accounts of special investigations. In recent years an evening address of general interest has been arranged for the annual meeting, which was given this year by the Prince of Monaco, who came to the United States to receive the Agassiz medal conferred upon him last year by the academy

In his address, Prince Albert described his oceanographic investigations for which he built and equipped four yachts, the *Hirondelle* I and II, and the *Princess Alice* I and II. The first *Hirondelle* of 1885 was a schooner of 200 tons and the second *Hirondelle* of 1911 is a steel steamer of 1,650 tons. With these yachts he had explored the sea from the Canaries to Spitzbergen. Apparatus had been devised for sounding the depths of the ocean and the upper air. In his voyages extensive explorations had been carried out, including oceanic soundings to a depth of 20,000 feet, and drag-net catches to a depth of 18,000 feet. Prince Albert also referred briefly to his explorations of the caves of southern France and northern Spain, which have brought to light a series of mural paintings by the men of the Old Stone Age. To house the collections of his sea and land explorations he has erected two museums, one at Monaco for ocean life and one at Paris for early human remains and works of art. At the annual dinner, President Walcott in awarding the Agassiz medal, told of the desire expressed by Sir John Murray, on his visit to this country, to leave a fund to commemorate Alexander Agassiz, which took the form of the Agassiz Gold Medal for "original contributions to the science of oceanography"; and Dr. W. H. Dall, of the Smithsonian Institution, described the scientific researches of the Prince of Monaco in the investigation of ocean currents and ocean life, including voyages in his especially equipped yachts from the Azores to the Arctic. Other medals of the academy were presented as follows: To Dr. Charles D. Walcott, secretary of the Smithsonian Institution and president of the academy, the first award of the Mary Clark Thompson Medal for distinguished achievement in geology and paleontology; to Dr. P. Zeeman, of Amsterdam, Holland, the Henry Draper Gold Medal for eminence in investigations in astronomical physics; to Rear Admiral C. D. Sigsbee, U. S. N., retired, the Agassiz Gold Medal for eminence in investigations in oceanography; to Dr. Robert Ridgway, the Daniel Giraud Elliot Gold Medal for his studies of the birds of North America; to Dr. C. W. Stiles, the Gold Medal for eminence in the application of science to the public welfare, in recognition of his work on the hookworm disease.

Dr. Albert Einstein, to whom Columbia University last year awarded the Barnard medal on the recommendation of the National Academy of Sciences, was present at the meeting. He was welcomed by President Walcott in the following words:

It is a happy privilege to greet you on behalf of the National Academy

PRESIDENT HARDING, PROFESSOR AND MRS. EINSTEIN AND MEMBERS OF THE NATIONAL ACADEMY OF SCIENCES AT THE WHITE HOUSE

of Sciences. The academy rejoices to bring its tribute of homage to the brilliant and penetrating mind which has so greatly enriched the philosophy of ultimate truth. We congratulate you on the universal appreciation of your investigations which has outrun and overleaped the limitations and barriers associated with nationalities and with the times. To men everywhere your name, in association with the abstruse subject of your investigations, has become a household word. We welcome you to our scientific meetings and especially to the social hours which intervene, during which the members of the academy hope to have the pleasure of meeting and learning to know you as a friend.

In reply Professor Einstein in substance said:

It gives me great pleasure to meet here so considerable a part of the scientific investigators of America and to become personally acquainted with them. I thank you for your friendly invitation and for the very hearty reception which has been accorded me. The appreciation of my scientific work, which has just been expressed, embarrasses me. When a man after long years of searching chances upon a thought which discloses something of the beauty of this mysterious universe, he should not therefore be personally celebrated. He is already sufficiently paid by his experience of seeking and finding. In science, moreover, the work of the individual is so bound up with that of his scientific predecessors and contemporaries that it appears almost as an impersonal product of his generation. The fact of this close spiritual association leads me to the last point that I have upon my heart to say. Our perturbed time has through the action of political misfortune partly impaired that community of labor that is so important for science. I should like to express the hope that the field of activity of scientific men may be reunited and that the whole world will soon again be bound together by common work.

ELECTIONS BY THE NATIONAL ACADEMY OF SCIENCES

At the business session of the academy the president, Dr. Charles D. Walcott, presented his resignation, but at the earnest request of the academy, he consented to serve the remaining two years of his term. The resignation of the foreign secretary, Dr. George E. Hale, was accepted with regret, and with the expression of high appreciation of his able work in that office. Dr. R. A. Millikan was elected foreign secretary, to complete the unexpired term of Dr. Hale. Dr. Hale was elected a member of the council, and Dr. Raymond Pearl was reelected.

The following were elected to membership:

Frank Michler Chapman, American Museum of Natural History.

William LeRoy Emmet, General Electric Company, Schenectady, N. Y.

William Draper Harkins, University of Chicago.

Ales Hrdlicka, United States National Museum.

Arthur Edwin Kennelly, Harvard University.

William George MacCallum, Johns Hopkins University.

Dayton Clarence Miller, Case School of Applied Science.

George Abram Miller, University of Illinois.

Benjamin Lincoln Robinson, Harvard University.

Vesto Melvin Slipher, Lowell Observatory.

Lewis Buckley Stillwell, 100 Broadway, New York.

Thomas Wayland Vaughan, United States Geological Survey.

Donald Dexter Van Slyke, Rockefeller Institute.

Henry Stephens Washington, Geophysical Laboratory.

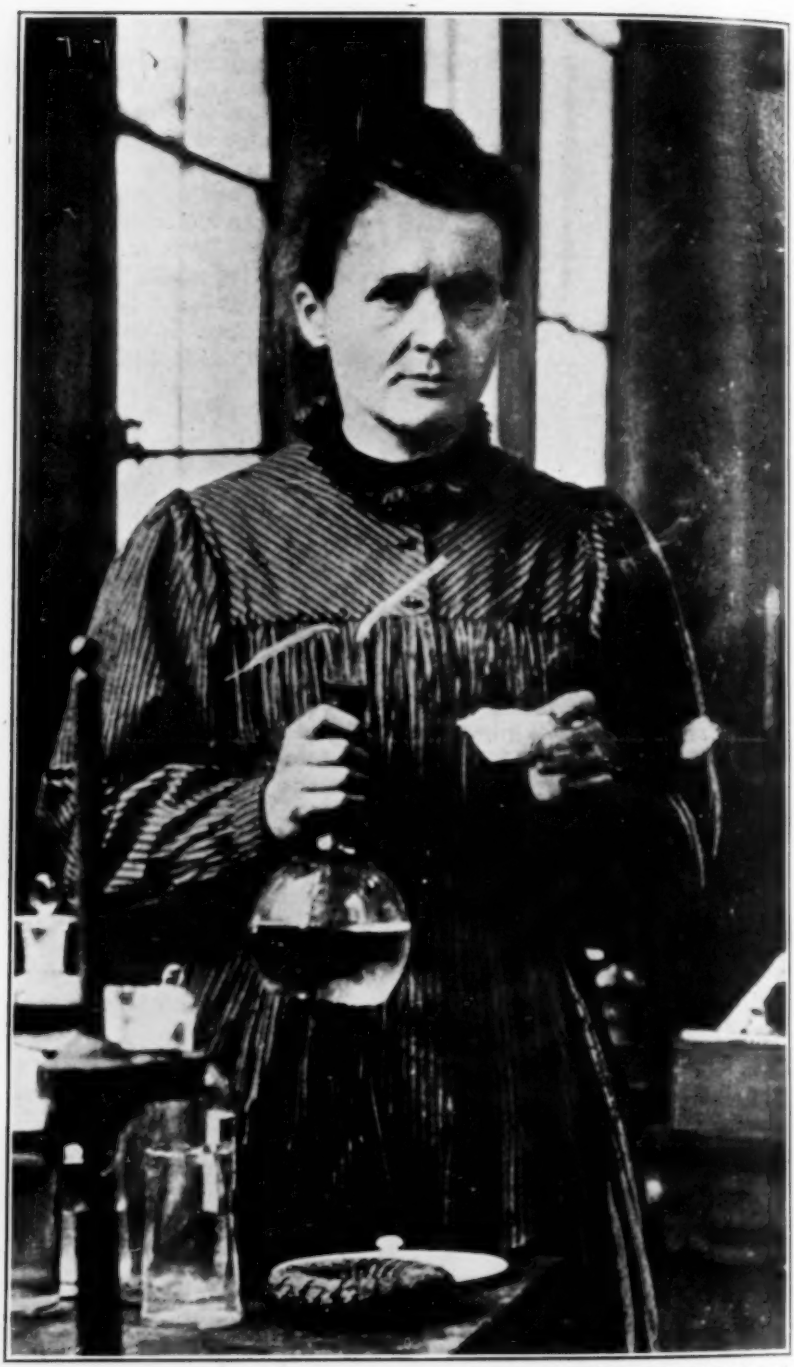
Robert Sessions Woodworth, Columbia University.

Foreign Associates

William Bateson, John Innes Horticultural Institution, Merton Park, Surrey, England.

C. Eijkman, University of Utrecht, Holland.

PRESIDENT HARDING, PROFESSOR AND MRS. EINSTEIN AND MEMBERS OF THE NATIONAL ACADEMY OF SCIENCES AT THE WHITE HOUSE



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MME. CURIE IN HER LABORATORY WHEN ENGAGED IN HER STUDIES OF RADIUM

MME. CURIE'S VISIT TO AMERICA

Mme. Marie Sklodowska Curie, accompanied by her two daughters, is spending five weeks in the United States. Representing France and Poland, the high intellectual achievement of women, and at the same time science which transcends the limits of nationality and of sex, she has received a welcome commensurate with her services and her distinction. In view of the widespread accounts of her work and of the honors conferred upon her, it is only necessary here to join in the universal expression of welcome and of admiration.

In her first address, which was made to the students of Vassar College, Mme. Curie expressed the value of research in pure science to the general welfare, the recognition of which will be greatly forwarded by the universal interest taken in her visit: She said:

> We must not forget that when radium was discovered no one knew that it would prove useful in hospitals. The work was one of pure science. And this is a proof that scientific work must not be considered from the point of view of its direct usefulness. It must be done for itself, for the beauty of science, and then there is always the chance that a scientific discovery may become, like radium, a benefit for humanity. But science is not rich; it does not generally meet recognition before the material usefulness of it has been proved. The factories produce many grams of radium every year, but the laboratories have very small quantities. That is true of my laboratory, and that is why I am very grateful to the American women who wish me to have more radium and are giving me the opportunity to go on with my work.

SCIENTIFIC ITEMS

We record with regret the death of Henry Platt Cushing, professor of geology in Western Reserve University; of George Frederick Wright, the geologist, professor emeritus of the harmony of science and religion at Oberlin College, and of Albert Cable Hale, formerly secretary of the American Chemical Society.

At the recent meeting of the American Chemical Society at Rochester, Professor Charles F. Chandler and Dr. William H. Nichols were elected honorary members of the society.

The American Philosophical Society has elected members as follows: Herman V. Ames, Philadelphia; George David Birkhoff, Cambridge; John J. Carty, Short Hills, N. J.; Frank M. Chapman, New York; Henry Crew, Evanston, Ill.; Benjamin M. Duggar, St. Louis; John Marshall Gest, Philadelphia; Charles Homer Haskins, Cambridge; Lawrence J. Henderson, Cambridge; J. Bertram Lippincott, Philadelphia; Hideyo Noguchi, New York; Thomas B. Osborne, New Haven; Charles J. Rhodes, Philadelphia; Vesto M. Slipher, Flagstaff, Ariz.; David White, Washington.

The trustees of the estate of the late John W. Sterling, to whom the residue of the estate was left in the interest of Yale University, have established two additional Sterling professorships at Yale; one of these is to be assigned for the present to mathematics, one to physiological chemistry. Professor Ernest W. Brown, of the department of mathematics, has been assigned to one of these professorships, and Professor Lafayette B. Mendel, professor of physiological chemistry, has been assigned to the other. Four Sterling professorships have now been established, the other two being the new professorship of education recently filled by the appointment of Frank E. Spaulding, formerly superintendent of public schools in Cleveland, Ohio, and the new professorship of chemistry recently filled by the appointment of Professor John Johnston, formerly secretary of the National Research Council. Each of these professorships has an endowment of about $225,000.

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MME. CURIE AT THE TIME OF HER ARRIVAL IN THE UNITED STATES

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